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GENERALIZED SELECTION CHARTS FOR BOMBERS POWERED
BY ONE, TWO, FOUR, AND SIX 2000-HORSEPOWER ENGINES
By M. J. Brevoort, G. W. Stickle, and Paul R. Hill

Langley Memorial Aeronautical Laboratory
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MEMORANDUM REPORT

for

Army Air Forces, Materiel Command

GENERALIZED SELECTION CHARTS FOR BOMBERS POWERED BY ONE, TWO, FOUR, AND SIX 2000-HORSEPOWER ENGINES

By M. J. Brevoort, G. W. Stickle, and Paul R. Hill

SUMMARY

A study has been made of the performance of bombers powered by one, two, four, and six 2000-horsepower engines supercharged to 25,000 feet. The performances are computed and are based on drag coefficients about equal to the best obtained on modern airplanes and on weight estimates obtained from a study of modern Army Air Forces airplanes.

The performances of each type are summarized in performance selection charts having coordinates of power loading and wing loading. By placing all performances on one chart the interrelationship of the performances as well as their dependence on power loading and wing loading is apparent.

The relative performances of the bombers with different number of engines are compared at constant power loading, showing the performance trends due to varying the number of 2000-horsepower engines and size of the bombers. A brief discussion of the basic factors creating these trends is given.

The assumptions and values of the parameters upon which the charts are based are given in the appendix.

INTRODUCTION

This paper is a continuation of the work done in reference 1 concerned with the comparative performance that can be obtained with different types of airplanes and how this performance is affected by the parameters of the airplanes. This study is not intended to give a final answer to the problem, but it should be viewed as a

preliminary attempt to relate the broad phases of the problem and present those relationships in a systematic manner.

The selection of the right type of airplanes to be procured for the successful prosecution of the war is an extremely important and difficult task. The selection depends on many seemingly independent factors that are almost impossible to evaluate accurately, such as, the location of the theater of the war, the tactics to be employed, improvements in airplanes, engines, and fuels, the comparative performance that can be obtained with different types of airplanes, and many other unforeseen factors.

The problem thus involves aerodynamics, structures, tactics, strategy, and economics. This analysis considers some aerodynamic and structural phases of the problem.

Accordingly it is beyond the province of this study to suggest that one airplane is superior to another for military operations. It is more likely that, when all the aspects of the problem are given their proper weight, each type will be of value if it is used on missions suited to its performance, and no type is superior on all missions.

This report takes up the problem of performance as a function of number of engines. Systematic variation of parameters has been employed to make this analysis. It has been assumed that each airplane is designed with equal skill and that due allowance is made for the tendency of the larger airplanes to submerge the bodies in the wing.

This study has been based on the best information available to the Laboratory at the time of writing, but it is realized that in many ways the information is not complete or in a form that can be applied to the problem and, therefore, the study should be continued to incorporate new and more complete information as it becomes available.

The comparative performance of airplanes having different number of engines is difficult to evaluate from the performance of existing airplanes because the various types have widely different characteristics, such as,

engines of different power, different values of wing loading, and varying degrees of aerodynamic refinement.

If one were able to design a series of airplanes having from one to six engines of the same size so that each airplane had the same wing and power loading, the same aerodynamic refinement, the same ratio of bomb load to gross load, then the relative performance of these airplanes would give the answer. Such an experiment is too expensive and too time-consuming to be practicable. In fact, by the time the largest airplane was finished, small airplanes with larger engines and aerodynamic improvements would have been built and the whole picture would again be in a confused state.

Due to the difficult nature of the problem, the most practicable method of attack is first by an analysis making systematic assumptions of weights, drags, and equipment in order to get a broad general picture. This report is the first part of the problem where the general picture is presented in the form of charts based on systematic assumptions.

Aerodynamic and structural tests of models are the most logical extension of this investigation. Results of such tests should be used in connection with new selection charts to show the performance of future airplanes.

SYMBOLS

C_l	coefficient multiplying the distributed load to give the effective distributed load
$C_{L_{T.O.}}$	lift coefficient at take-off
C_{D_0}	parasite drag coefficient
F	effective frontal area of the bodies on an airplane, square feet
f	load factor
K	dimensionless constant
L/D	lift-to-drag ratio
R	aspect ratio

S	wing area, square feet
t	root wing thickness divided by root chord
W	gross weight of airplane, pounds
W ₁	wing weight, pounds
W ₂	distributed weight on the wing, pounds

PRESENTATION OF CHARTS

Charts showing the performance trends in range, speed, rate of climb, and take-off distance plotted on the coordinates of power loading and wing loading are given in figure 1. Each point on these charts defines a complete and consistent airplane. The aerodynamic and structural parameters have been varied in a consistent manner so that the airplanes have equal load factors, wing thickness ratio, aspect ratio, propeller efficiency, and aerodynamic cleanness. These charts show performances that are aerodynamically and structurally consistent with the best airplanes that can be produced at the present time. The airplanes are all powered with 2000-horsepower engines supercharged to 25,000 feet altitude. The speed curves are calculated at 25,000 feet altitude and the range, rate of climb, and take-off distance curves are calculated at sea level. (See the appendix.)

Figure 1(a) applies to single-engine bombers; figure 1(b) to two-engine bombers; figure 1(c) to four-engine bombers; and figure 1(d) to six-engine bombers. By the use of these charts it is possible to determine the general trend in performances as affected by the number of engines. Comparisons for a few special cases where the take-off distance is fixed at 3000 feet are given in figures 2, 3, and 4.

Separate charts for each performance characteristic are given in figures 5-9. The performance can be read from these with greater accuracy than from the composite selection charts of figure 1. Included in this group are charts giving the maximum L/D, and charts giving the structural weights and carrying capacity of gasoline, oil, and bombs.

PERFORMANCE TRENDS

Comparison of the performance of the bombers with one, two, four, and six engines are made at a take-off distance of 3000 feet. For a given power loading the wing loading is selected to give this take-off distance and is the same for each type, so that, in reality, the comparison is also made at constant power loading and constant wing loading.

Figure 2(a) gives the maximum range of bombers with one, two, four, and six 2000-horsepower engines having a take-off distance of 3000 feet and carrying no bomb load. Figure 2(b) is similar to figure 2(a) except that part of the fuel is displaced by bomb loads. The bomb loads are proportioned according to the relative weight and power of the different types. More specifically, the ratio of bomb load to horsepower is 1.25. Magnitudes of bomb load are indicated on the figures.

Both figures give the same range trends. This simply shows that the magnitude of the bomb loads is an unimportant factor in the comparison as long as they are distributed in a fair manner. The greatest range obtained in the investigation is obtained with a four-engine bomber at the highest power loading, $W/P = 25$. At a power loading between 20 and 25 the four- and six-engine bombers are equal. Below this the six-engine bombers have the greatest range of the series. The maximum range of the two-engine bombers will be found to average about 85 percent of the range of the four-engine bombers over the range of power loading investigated.

Figure 3 shows the high speeds at a wing loading giving a 3000-foot take-off distance. A power loading of six, which is representative of pursuit airplanes, is included as a lower limit. At and below power loadings of 6 and 10, the single-engine airplane is faster than the two-engine airplanes. At higher power loadings, the speed continuously increases with an increase in the number of engines resulting in a difference in speed between the two- and six-engine bombers of from 6 to 10 percent. The relation between the single- and two-engine bombers may also be observed by comparing figure 6(a) and figure 7(a). There is a greater spread between the curves of constant speed on the two-engine bomber, the two-engine bomber being faster at high power loading and the

single-engine bomber faster at low. This is because of the nacelle drag at low power loading, and at high power loading the nacelles are more submerged in the wings.

It is also possible to make the comparisons showing the range of the different types at the optimum wing loading for range and the speed at the optimum wing loading for speed. However, this basis of comparison is inconsistent in that different wing loadings are used in the range and speed comparison. Also the differences in range and speed obtained by this method over that obtained at constant take-off distance is found to be trivial and the trends of range and speed with respect to number of engines is practically identical.

Figure 4(a) shows the rates of climb for airplanes with a 3000-foot take-off distance. There is no important variation in rate of climb with number of engines.

PARAMETERS AFFECTING PERFORMANCE TRENDS

One effect of increasing the number of engines is to more nearly distribute the weight of the power plants over the wing span thus tending to lighten the wing structure. However, this does not turn out to be the factor controlling wing weight, as will be pointed out.

For reasonably proportioned airplanes large increases in gross weight and size accompany large increases in power. This gives rise to scale effects which have an important effect on performance. There is a tendency for certain weights, such as crew and equipment, instruments, and armament, to increase much less rapidly than the gross weight, thus giving the larger bomber considerable advantage. Also the larger airplane tends to submerge the nacelles and fuselage to a much greater extent. As the scale increases these factors tend to increase the range. However, as the airplane and the airplane wing become larger, a greater thickness of material is required to resist the bending stresses and the greater thickness of the wing makes necessary a greater weight of intersurface structural members. This factor, rather than the greater distribution of engine weight over the span, is the controlling factor in wing weight. As a result the unit wing weight increases with scale. This factor eventually overcomes the favorable effects of scale, and an optimum

is reached beyond which range is decreased. These observations are for airplanes of a conventional form and may be considerably upset by flying wing or other types.

The greater speed of the larger bombers is due to the relatively smaller fuselages on the large bombers and a greater degree of submerging the fuselage and nacelles in the wings.

The power to fly the airplane in climb (exclusive of climbing power) varies with the fourth root of the airplane drag coefficient and inversely with the aspect ratio to the three-fourths power. Since the variation of drag coefficient is not large, the relative differences after taking the fourth root are quite small. Consequently, the rate of climb at a given power loading, wing loading, and aspect ratio are almost equal, as may be observed for the bombers of two, three, and four engines. The drop in rate of climb of the single-engine bomber is principally due to its lower aspect ratio. Thus, for airplanes of the same power loading, wing loading, aspect ratio, and propeller efficiency the rates of climb should be substantially equal even though there exists a difference in degree of aerodynamic cleanliness.

Take-off distance has been assumed to be completely a function of power loading and wing loading, and no variation of take-off distance with number of engines is shown.

ILLUSTRATION OF SELECTION CHARTS

In the normal use of a selection chart the interested party probably has a definite, preconceived idea of the type of mission, the desired number of engines, and the desired performance. The use of the performance selection chart is to choose the most satisfactory combination of performances for the type of mission for which the bomber is intended and at the same time to determine the proper power loading and wing loading. However, in order to inspect the selection charts for one-, two-, four-, and six-engine bombers, let us assume a set of minimum performance figures and find the type most nearly satisfying the specifications.

Let it be required to select an airplane with these requirements: maximum range of 8000 miles with a ratio

of bomb load to horsepower equal to 0.625, a high speed of 300 miles per hour with full load at 25,000 feet altitude, a rate of climb at sea level of 1000 feet per minute, and a take-off distance not to exceed 2000 feet.

The selection chart for the single-engine bomber (figure 4(a)) shows the 8000-mile-range curve failing to intersect the 300-mile-per-hour speed curve by a wide margin. Airplanes defined by power and wing loadings in the area above and within the arc of the 8000-mile-range curve have ranges above the minimum range requirement. Only airplanes on or in the area below the 300-mile-per-hour speed curve have speeds equal to or in excess of 300 miles per hour. Hence, although the single-engine bomber can have either an 8000-mile range or a 300-mile-per-hour high speed, a given airplane cannot have both.

The selection chart for two-engine bombers shows the 8000-mile-range curve does not quite intersect the 300-mile-per-hour speed curve and just fails to intersect the 1000-foot-per-minute-climb curve so that the two-engine bomber fails by a narrow margin to fulfill the requirements set up. If the maximum range requirement were but 7400 miles, the speed, take-off, and climb requirements remaining the same, a two-engine bomber would be satisfactory. It is interesting to note that in this case only the two-engine bomber with a power loading of 15.6 and wing loading of 37 fulfills the requirements.

Referring to the selection charts for the four-engine bombers, figure 4(c), area above the 8000-mile-range curve satisfies the range requirement; area below the 300-mile-per-hour speed curve satisfies the speed requirement; area to the left of the 2000-foot take-off curve satisfies the take-off requirement, and area below the 1000-foot-per-minute-climb curve satisfies the climb requirement. A small area bounded by the range, speed, take-off, and climb curves just referred to represents bombers satisfying all of the specified requirements and is indicated by heavied lines on the chart. The four-engine bomber should have a power loading of 15 or 16 pounds per horsepower and a wing loading of about 35 pounds per square foot.

Referring to the selection chart for six-engine bombers, figure 4(d), we note that an area similar to that found satisfactory on the four-engine bomber chart also exists on the six-engine chart and fulfills the

specifications. In fact the same power loading and wing loadings are found to be satisfactory.

Aerodynamically the four and six-engine bombers are equal in this example, and the choice between them must be made on some basis other than aerodynamic.

It must be emphasized that the assumed specifications are merely for illustration and therefore no claims are made for the particular answers of power loading and wing loading obtained.

An inspection of the selection charts shows that the optimum wing loading for range and also for speed increases with the number of engines. These effects are mainly due to the changes of structural weight and speeds with changes of scale although they may be colored somewhat by the simplifying assumptions made in the analysis.

EFFECT OF OVERLOADING

It frequently happens that there is reason to revise the design of an airplane, to increase its gasoline carrying capacity, or otherwise to increase its weight. The gross weight of the airplane is increased while the wing area remains constant. This procedure is similar to a practice referred to as "overloading," although in our case we shall assume that the structure is suitably strengthened for the extra load. If the gross load is increased the increase in range may be thought of as due to the increase in power loading; the increase of wing loading is merely one of the results of the process. It is readily shown that airplanes with an initially low wing loading are far more adaptable to overloading than those with an initially high wing loading.

For example, on the two-engine bomber selection chart, figure 4(b), let us choose two bombers, one with a power loading and wing loading of 10 and 25 and the other with a power loading and wing loading of 10 and 60, represented by points A and B on the chart. Let it be desired to increase the disposable load and other weights until the gross weights are increased from 40,000 to 60,000 pounds, thus increasing the power loadings in each case to 15 pounds per horsepower. Because wing area and power are constant the increases in power loading and

wing loading are proportional, and overloading is represented by straight lines through the origin. Thus, we locate the revised airplanes at A' and B' on lines radiating from the origin, passing through A and B. The initial and final performances are tabulated below.

Bomber A						Bomber B					
W/P	W/S	Range	Take-off	Speed	Climb	W/P	W/S	Range	Take-off	Speed	Climb
10	25	4700	800	320	2250	10	60	4700	2300	360	1800
15	37	7200	1900	305	1150	15	90	6400	6000	315	700

Line A-A' is practically perpendicular to the range curves, angles obliquely to the take-off curves, and is almost parallel to the speed curves. As a result the range increases rapidly while the take-off and speed are not affected very rapidly. The line B-B' runs obliquely with respect to the range and almost perpendicular to the take-off curves; as a result we approach a point where it is impossible to improve the range and the take-off distance increases far too rapidly. An illustration could be cited of a popular bomber originally designed with a low power and wing loading, which has had the gross weight greatly increased with very satisfactory results. Others originally designed with a high wing loading are quite restricted in increasing the gross weight.

LIMITATIONS OF THE ANALYSIS

Range is greatly dependent on the ratio of fixed and structural weights to gross weight because this ratio has a direct bearing on the amount of fuel which can be carried. It follows that the relative range merits of the several types depends on the magnitudes of the fixed weights chosen as representative for the different types and on the load factors for various loading conditions. Both speed and range are dependent on the relative size of the fuselages and the degree to which the fuselage and nacelles are submerged in the wing. Therefore, for airplanes with fixed weights, load factors, and effective frontal areas varying in a different manner from those

chosen for this analysis it must be expected that the performance trends will be modified accordingly.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 6, 1942.

APPENDIX

Power Plants

The bombers are all powered by 2000-horsepower engines. It is assumed that each requires a nacelle projected frontal area of 25 square feet for adequate housing and the admission of all cooling air. Weight estimates are made to include all auxiliary equipment necessary for full power operation to 25,000 feet. The curves of minimum specific fuel consumption and engine rpm for operation at minimum specific fuel consumption are given in figure 10.

Drags

Drag coefficients are taken to give parasite drags approximately equivalent to the parasite drag of modern Air Force airplanes. The drag coefficient of the wing and tail based on wing area is 0.0120 and of the fuselage and nacelles is 0.12 based on effective frontal area. The effective frontal area is the actual frontal area less an allowance made because the fuselage and nacelles are not complete bodies, but are partially submerged in the wing. The effective fuselage area for a given family of airplanes is taken to vary with the $2/3$ power of the gross weight. The values of effective fuselage and total effective nacelle frontal area for the several families of bombers and the manner in which they are assumed to vary with the gross weight is given in figure 11. Of two bombers with the same gross weight and different number of engines, the bomber with the larger number of engines has the smaller fuselage since more of the weight is in the nacelles.

The total parasite drag coefficient of the bombers may be expressed by two terms representing the wing plus tail, and the fuselage plus nacelles as follows:

$$C_{D_0} = 0.0120 + 0.12 F/S$$

F represents the effective frontal area of fuselage plus nacelles and S the wing area.

An addition to the parasite and ideal induced drag with increasing lift coefficient is assumed and expressed as an increase in the induced drag of an elliptical wing.

Thus, the expression for induced drag is divided by a "span factor" as in the equation

$$D = C_{D_0} q S + (W/b)^2 / e q$$

The value of e is taken as 0.8 in this analysis.

Propeller Efficiency and Cooling Power

It was assumed that a propeller efficiency of 85 percent could be realized. In order to simplify the performance computations, it is assumed that cooling power is proportional to brake power. This assumption makes it possible to take account of the cooling losses by an equivalent reduction of the propeller efficiency. Five percent of the brake power was allowed for cooling, giving an effective propeller efficiency of 80 percent. This value was used in all performance calculations. In order to make a constant value of 80 percent effective propeller efficiency applicable to the range calculations for the condition of maximum L/D and minimum specific fuel consumption, it was necessary to make these computations at sea level.

Aspect Ratio

The variation of range is not critical with considerable variation of aspect ratio. A value of 12 has been used throughout the charts for the two-, four-, and six-engine bombers, while a value of 9 has been used for the single-engine bombers.

Load Factor

A design load factor of 4 with a 2000-pound bomb load has been used for this analysis. This is sufficient to protect against a standard gust of 30 feet per second. Very modest maneuverability is afforded by this load factor.

Wing Thickness

A 20-percent wing-thickness ratio at the root chord was used for all the airplanes. This wing is thick enough to keep the wing weight reasonable but not thick enough to cause a high drag or to experience compressibility at maximum speed.

Weight

After a study of Air Forces airplanes, it was assumed that:

1. Fuselage weight is 8 percent of airplane gross weight.
2. Landing-gear weight is 6 percent of airplane gross weight.
3. Tail weight is 10 percent of wing weight.
4. There are certain fixed weights which vary with the gross weight as in the following table:

Fixed Weights

Type	Gross weight	Engines and access.	Crew and equipment	Instruments and fix. equip.	Guns and armor
Single-engine	15,000	4500	800	500	1500
Do-----	25,000	4500	1000	500	2000
Do-----	37,500	4500	1200	600	2500
Do-----	50,000	4500	1200	600	3000
Two-engine	30,000	9000	1200	500	2000
Do-----	50,000	9000	1400	600	2570
Do-----	75,000	9000	1600	700	3300
Do-----	100,000	9000	1600	800	4000
Four-engine	60,000	18,000	1600	700	2500
Do-----	100,000	18,200	2000	800	3300
Do-----	150,000	18,500	2000	900	4100
Do-----	200,000	18,800	2000	1000	5000
Six-engine	90,000	27,000	1800	800	2800
Do-----	150,000	27,300	2000	900	3600
Do-----	225,000	27,750	2000	1000	4700
Do-----	300,000	28,200	2200	1100	5600

5. Weight of fuel system equals 0.55 pound per gallon of gasoline.
6. Weight of lubricating system equals 1.25 pounds per gallon of oil.

Sufficient tankage weight is included to obtain maximum range with no bomb load. The tanks are assumed to be carried in the wings.

Figure 12 is a chart showing the variation of the fixed weights. These weights are the weight of crew and their equipment, instruments, and certain fixed equipment, armament and armor. The chart shows the variation of these weights more readily than does the table. The general trend is for the increase in fixed weights to become less rapid with increasing gross weight. This follows since there is not much point to increasing the weight of instruments and the crew numbers beyond a certain amount and the need for an increase in the amount of armament with increasing bomber weight tapers off once all "blind" spots have been eliminated. The fact that a bomber with fewer engines than another of the same gross weight is assigned a larger fixed weight may be justified on the premise that it is considerably slower and therefore needs more defensive armament.

Wing Weight

Wing weight is determined by considerations of strength. An expression equating the internal resisting moment to the external bending moment at the center section gives the following relationship:

$$K = \frac{W - (C_1 W_2 + W_1)}{W_1} \times \frac{f R^{3/2} s^{1/2}}{t}$$

where K is a dimensionless constant dependent upon:

1. The distribution of lift along the span.
2. The strength weight ratio of the material used in the construction of the wing.
3. The perfection of the design as an efficient weight to strength beam. The higher the K , the more efficient the beam as a weight-carrying structure.

For simple loading conditions, such as those for pursuit airplanes where nearly all of the load is concentrated in the fuselage, it is to be expected that a value of $C_1 = 0$ would approximate the loading condition.

For multiengine bombers, where a large portion of the load is distributed along the wing, a value of C_1 between 0.5 and unity would be expected to approximate the loading condition. For the purpose of this analysis a value of $K = 100,000$ was used. A value of C_1 equal to 0.85 was used for the four- and six-engine bombers and C_1 equal to 0.75 for the single- and two-engine bombers. To solve this equation for wing weight if the value of the load to be carried in the wing is as yet unknown, W_2 may be conveniently expressed as the gross weight less the weight of the fuselage and the weight carried by the fuselage (including the tail surfaces), less the wing weight.

REFERENCE

1. Brevoort, Maurice J., Stickle, George W., and Hill, Paul R.: Generalized Selection Charts for Bombers With Four 2000-Horsepower Engines. NACA MR, May 11, 1942.

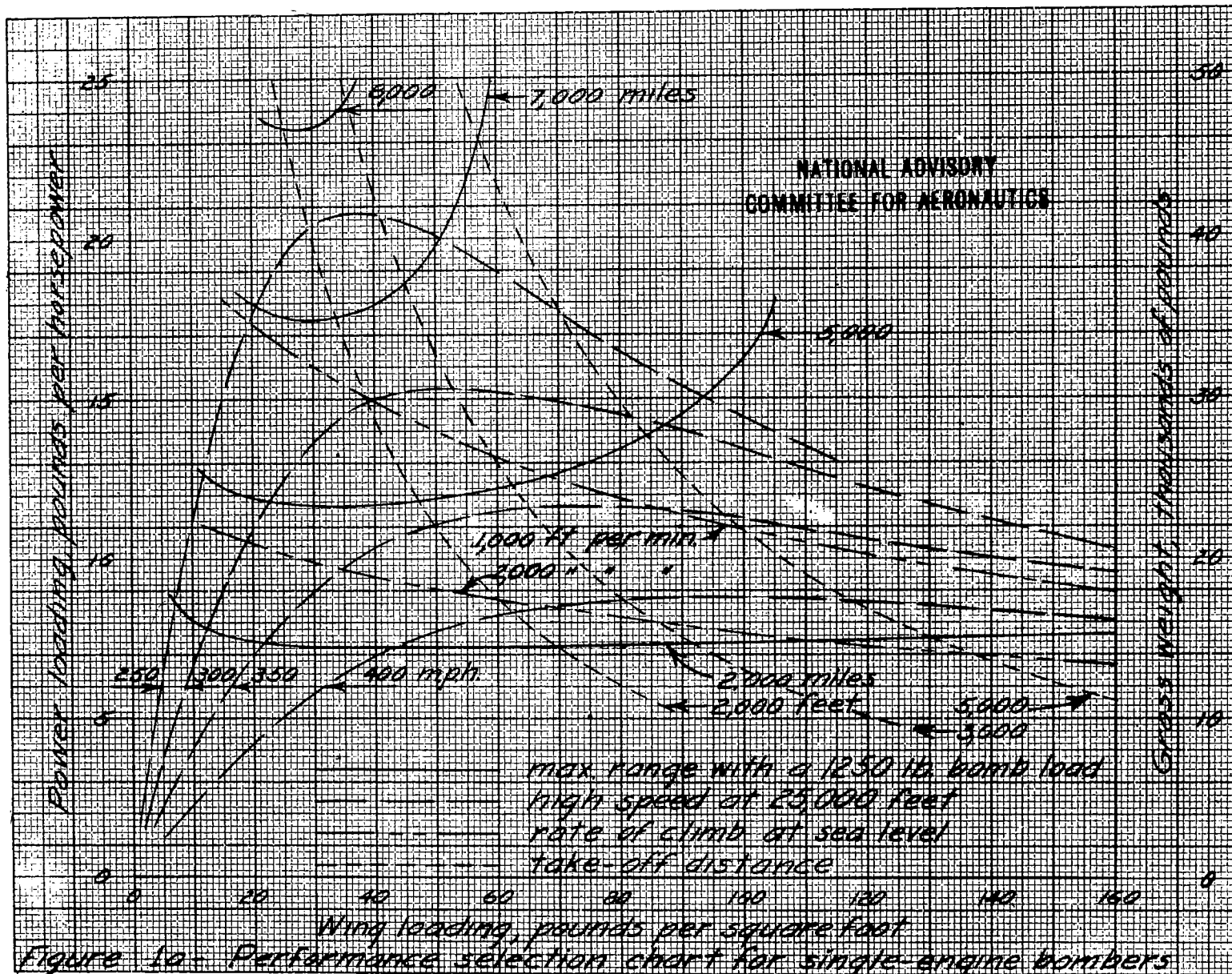
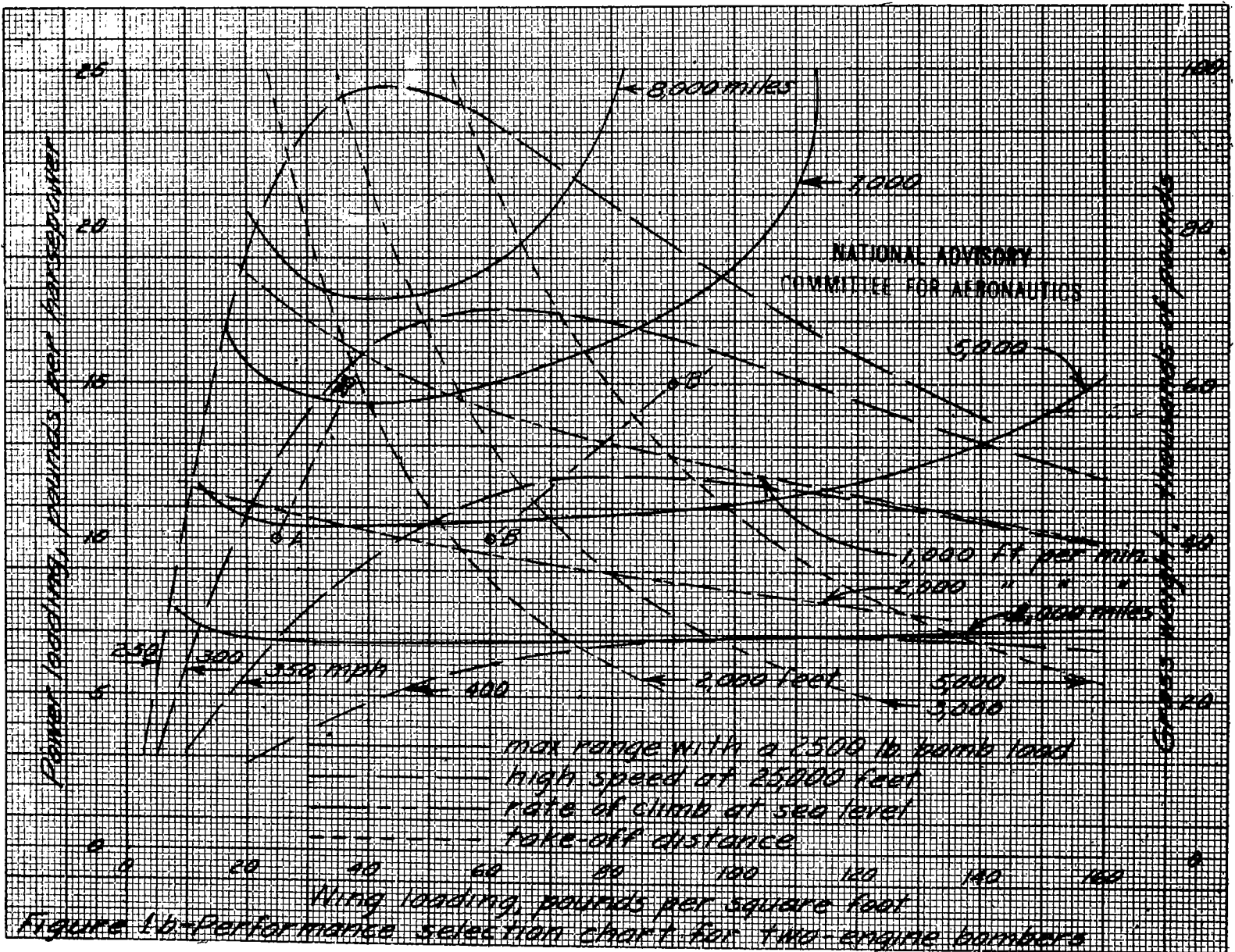
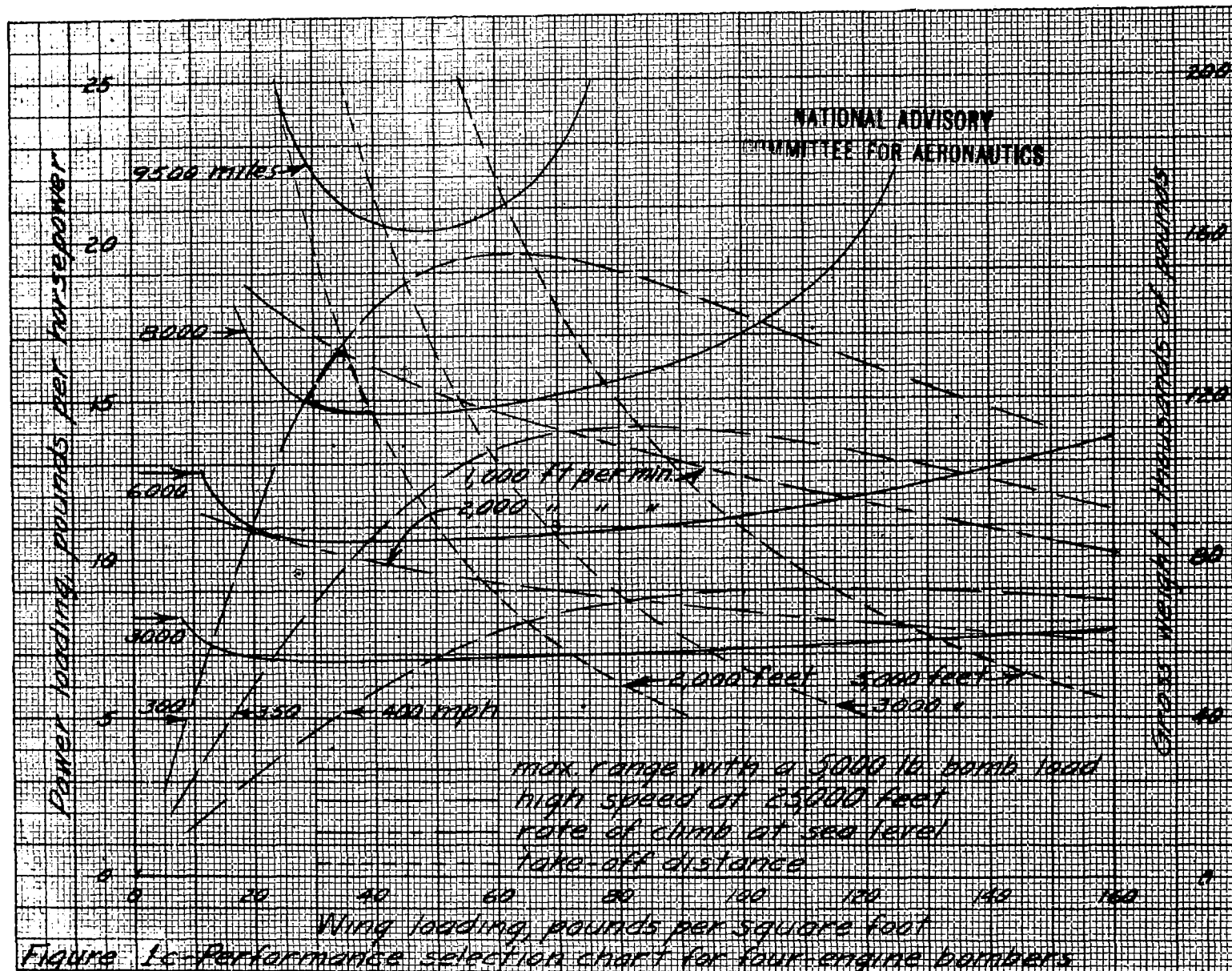
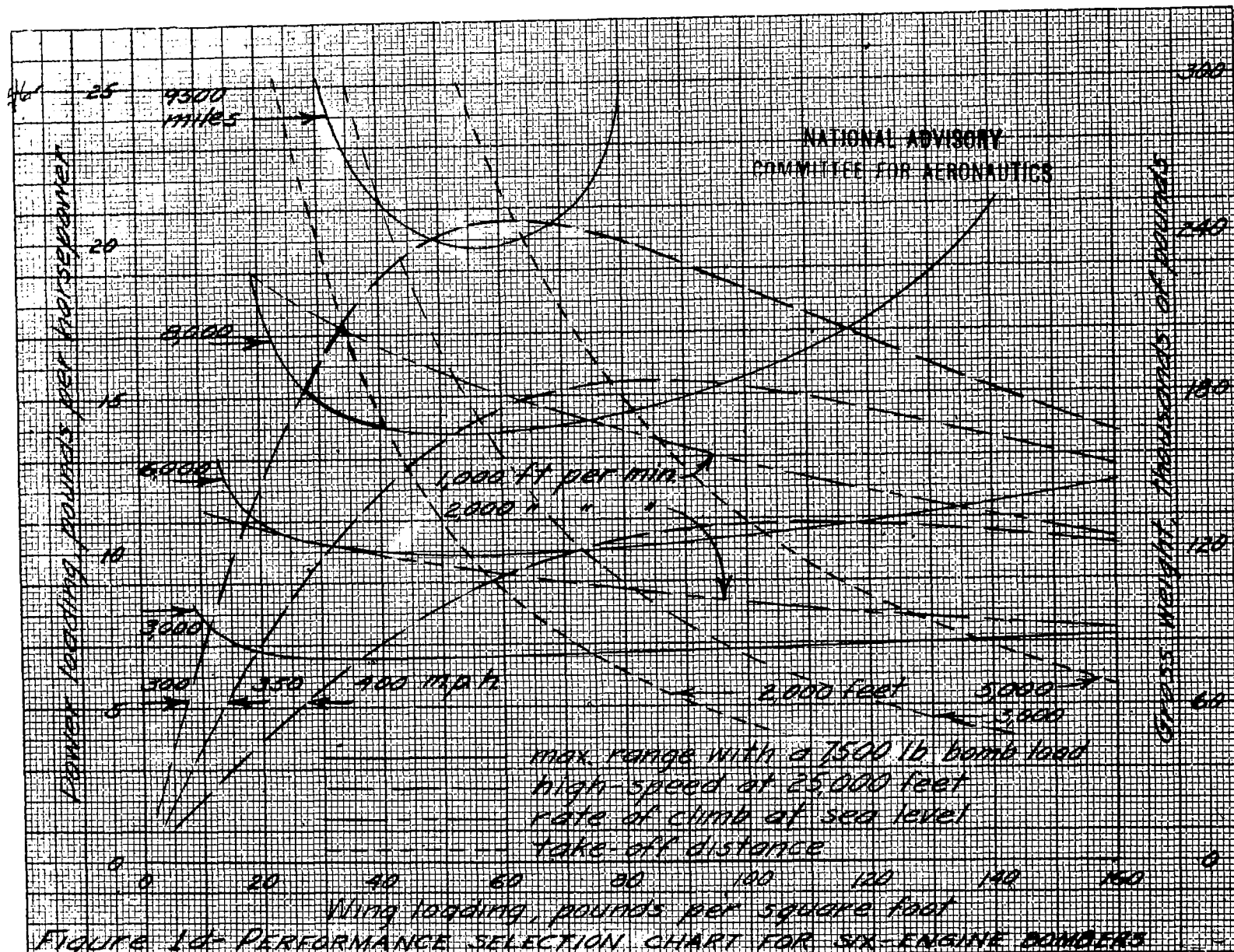
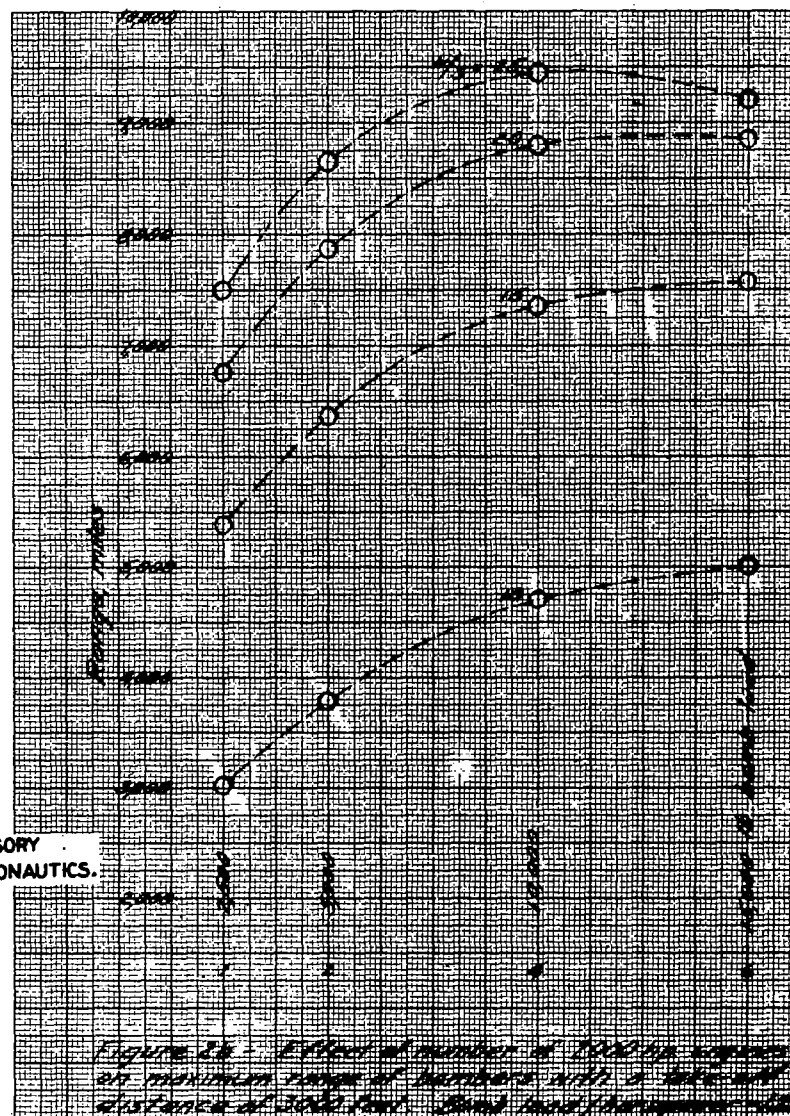
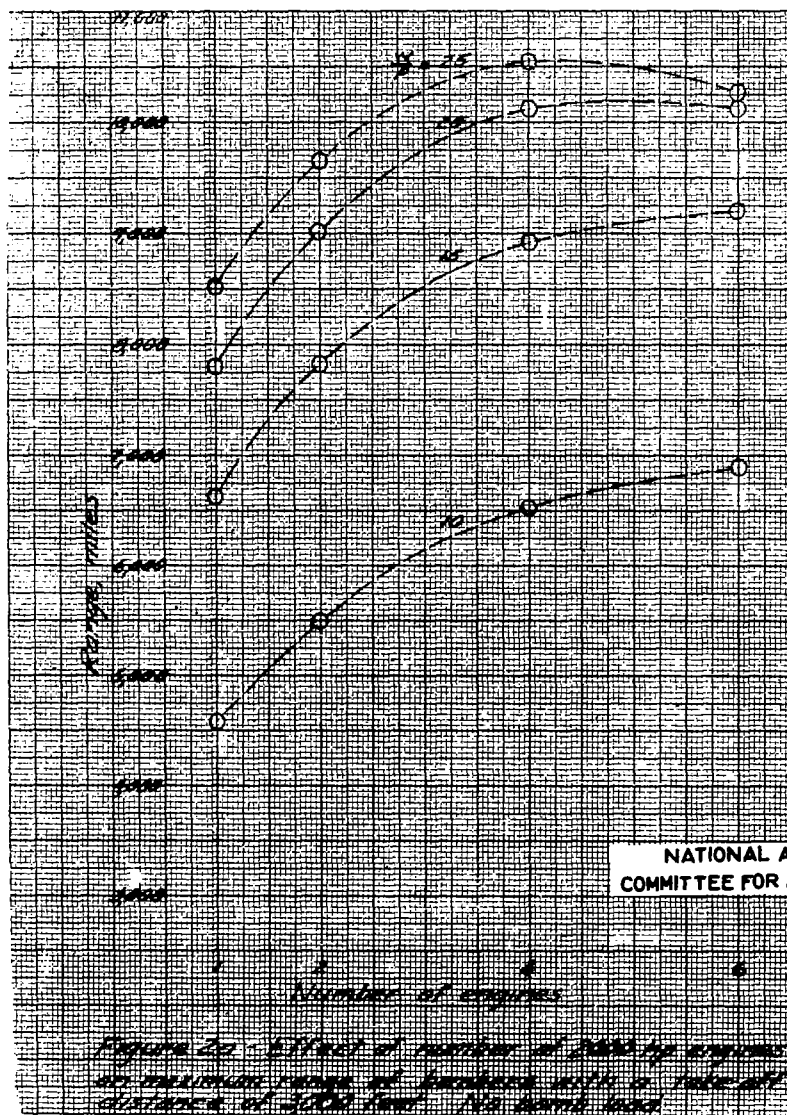


Figure 1a- Performance selection chart for single-engine bombers









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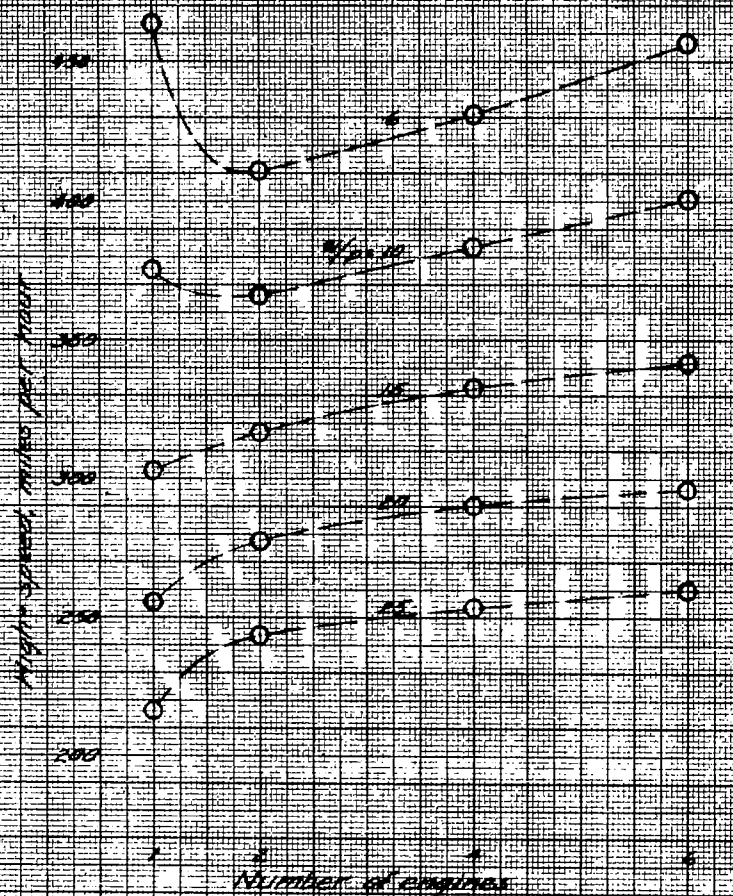


Figure 3. - Effect of number of 2,000 hp engines on high-speed of bombers with a take-off distance of 8,000 feet.

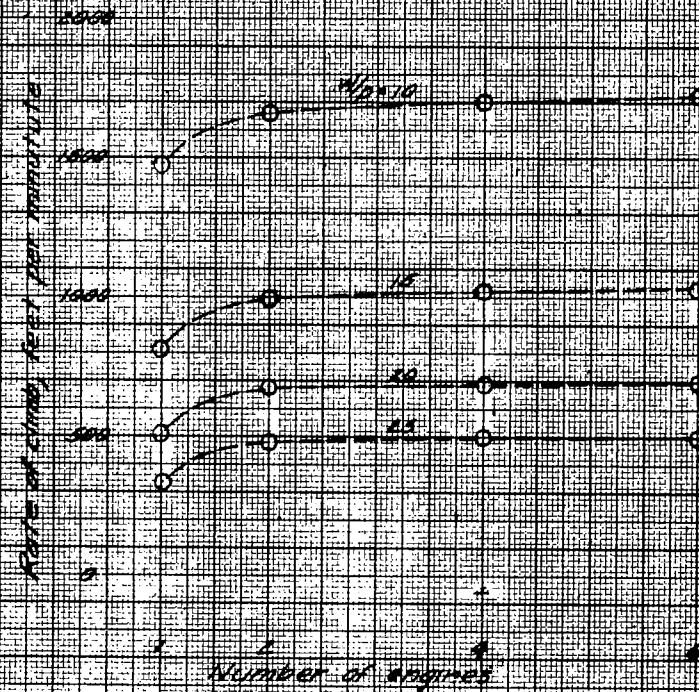


Figure 4. - Effect of number of 2,000 hp engines on rate of climb of bombers with a take-off distance of 3,000 feet.

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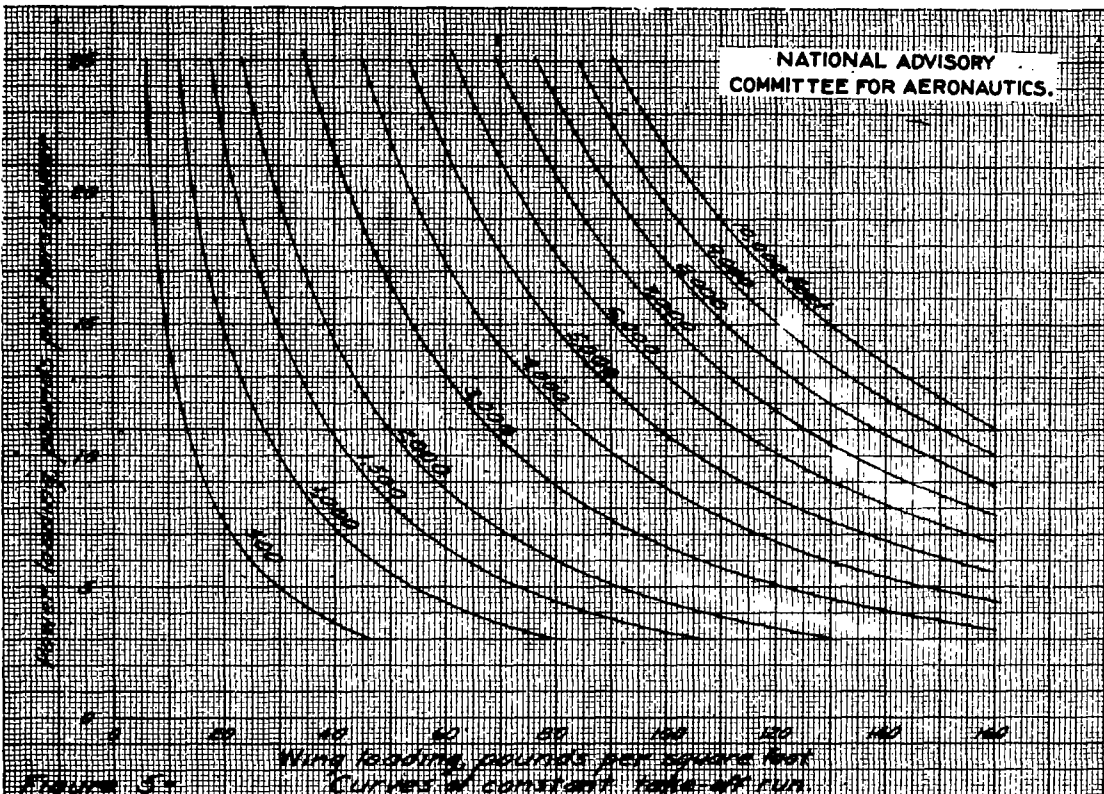
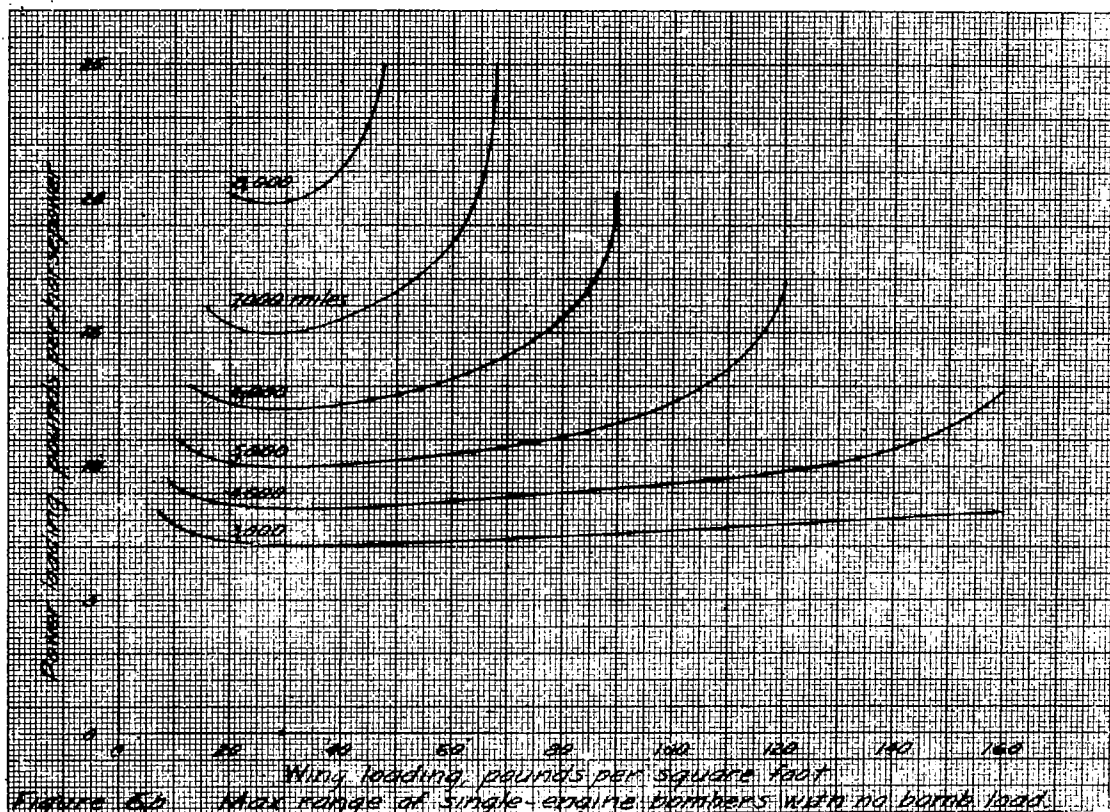
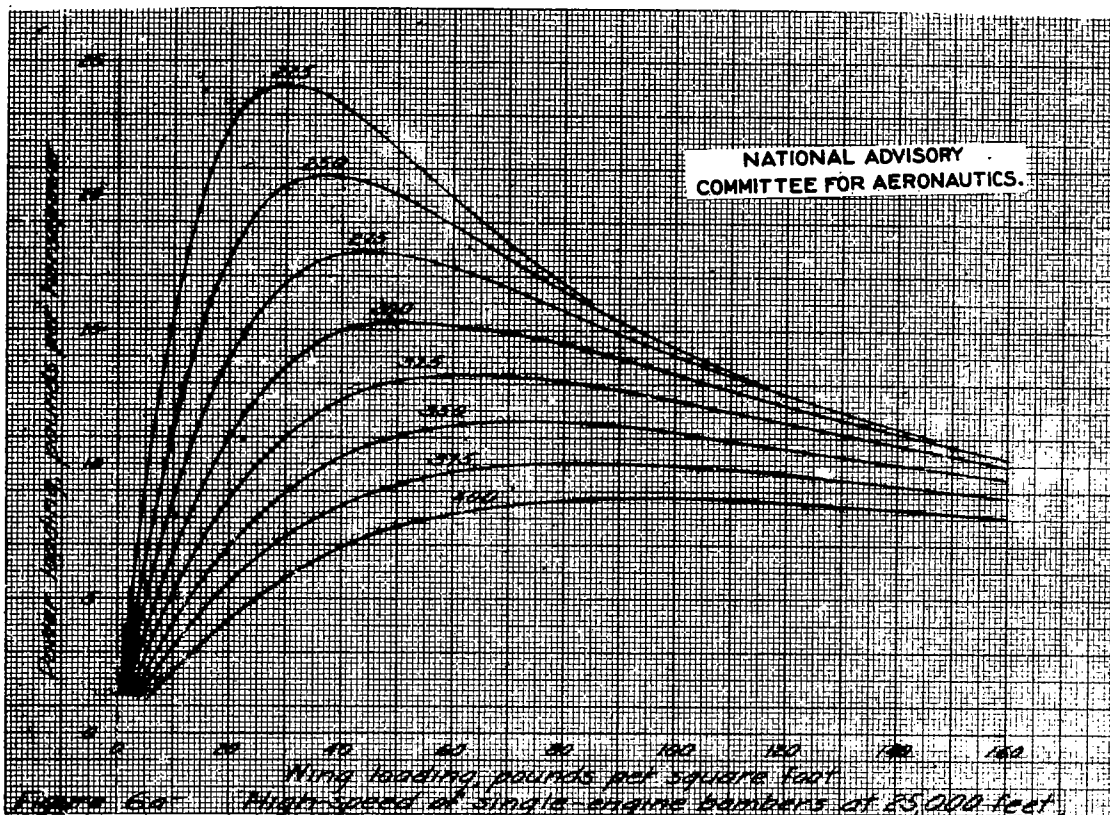
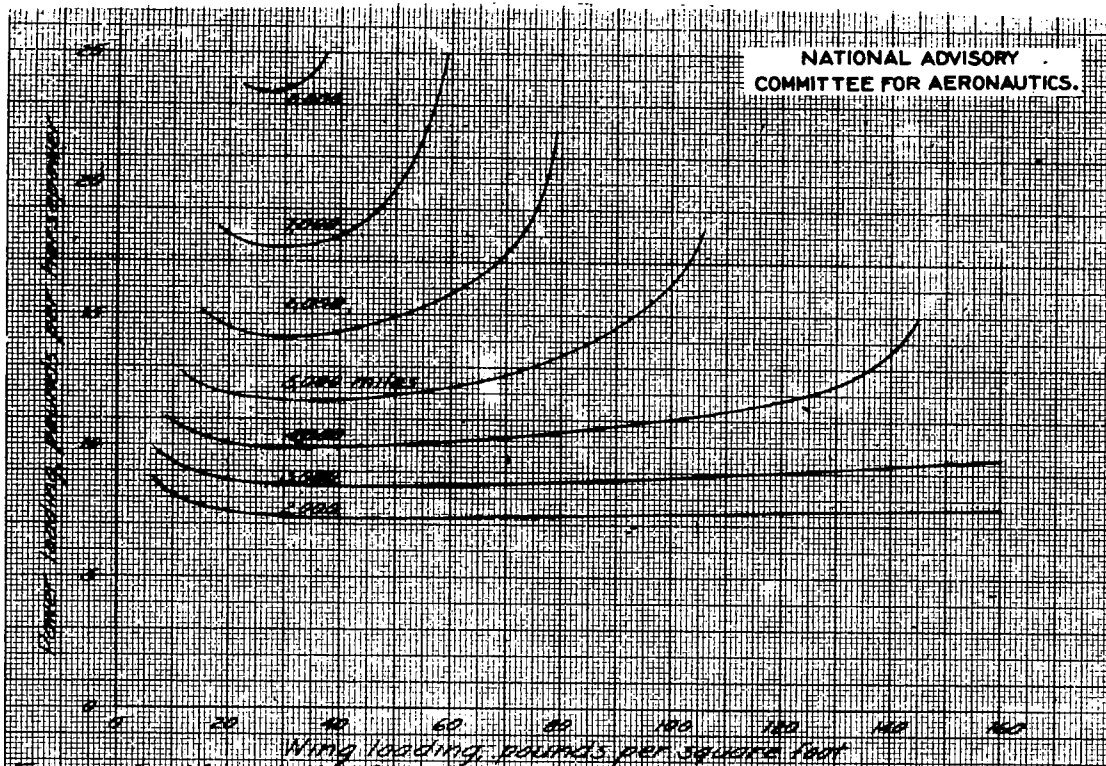


Figure 5-

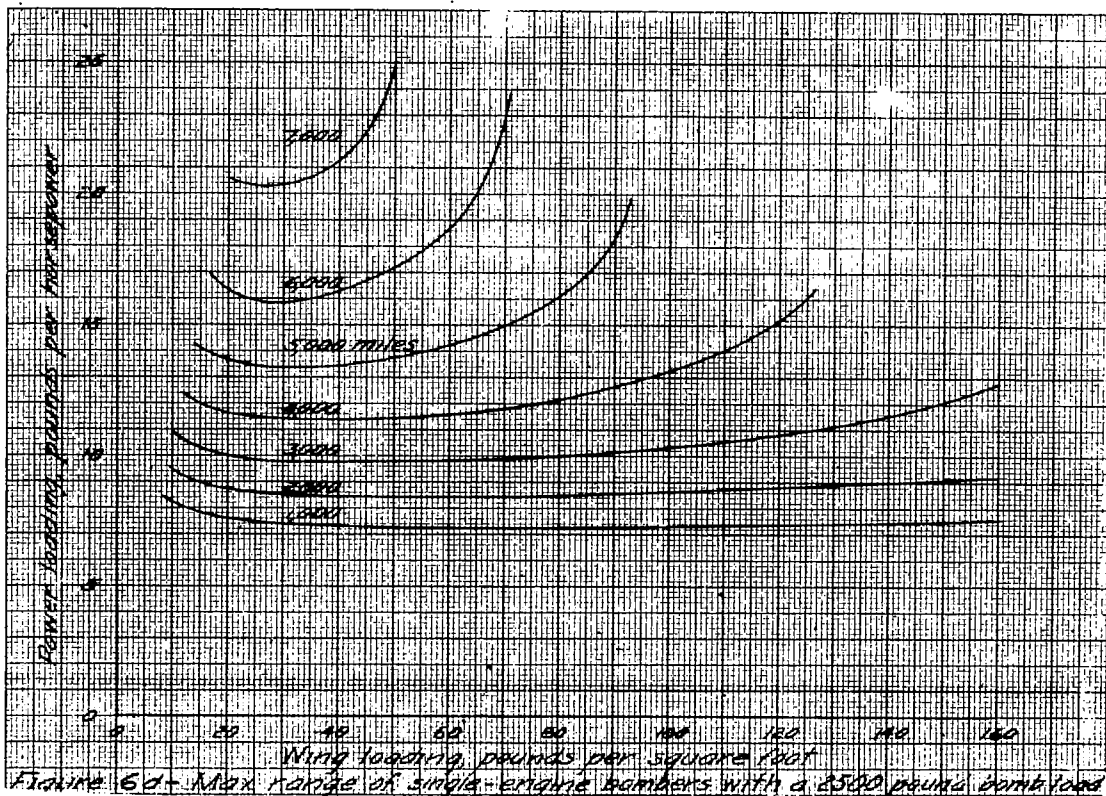
Curves of constant take-off speed.

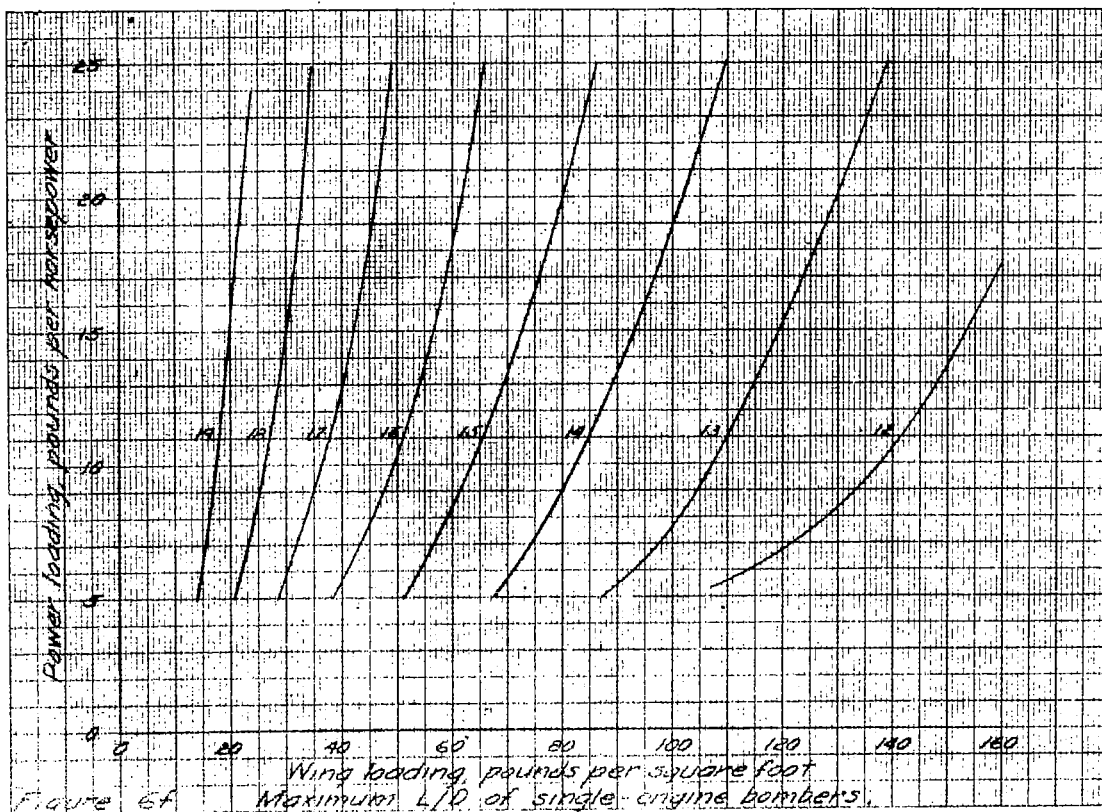
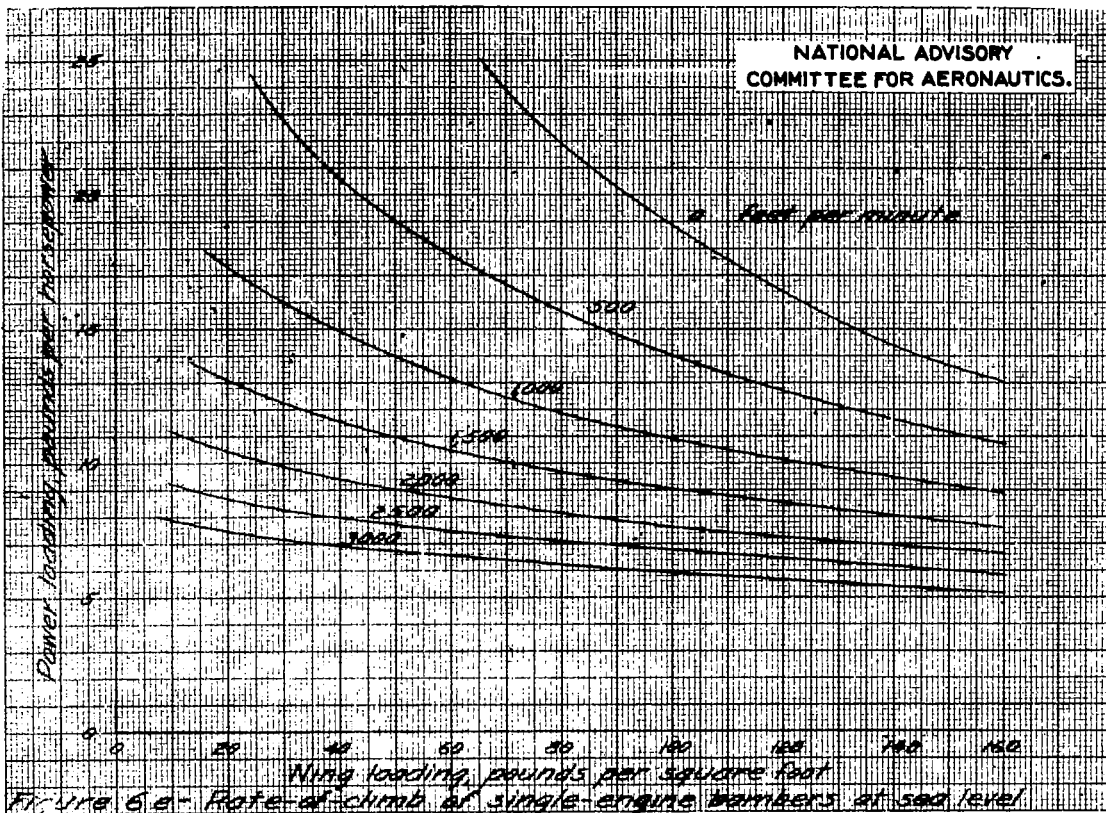


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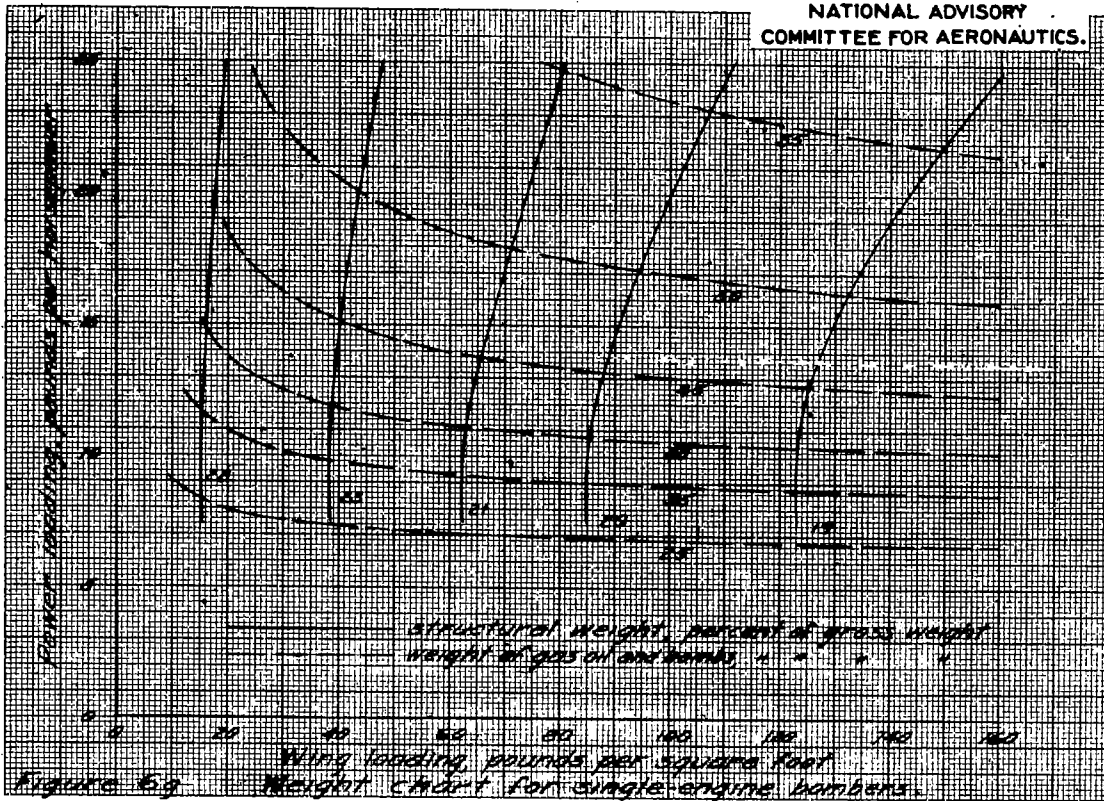


Figure 6g

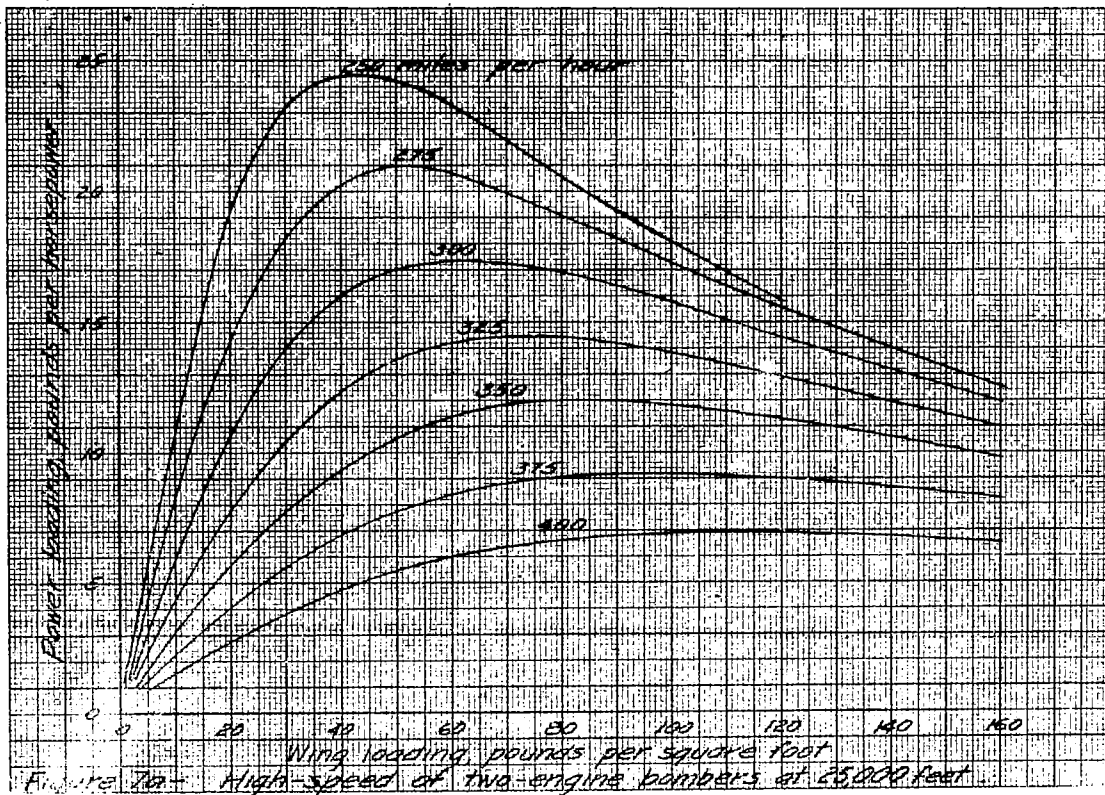
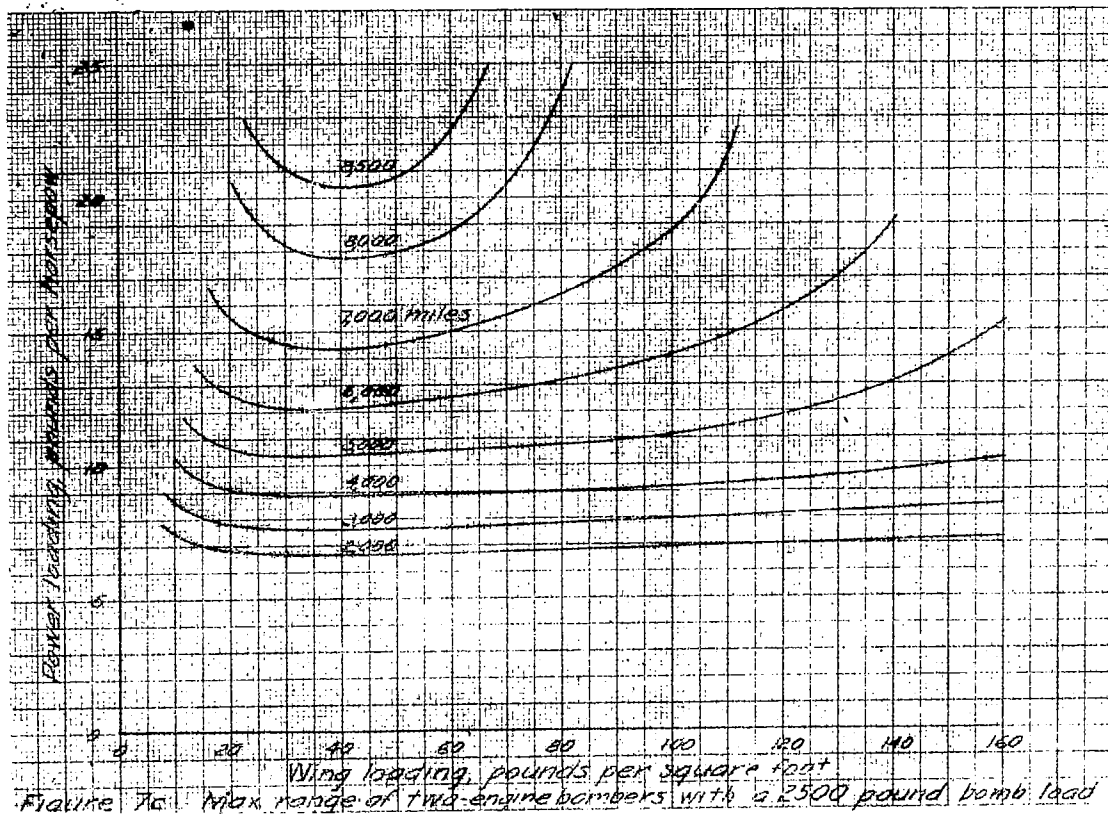
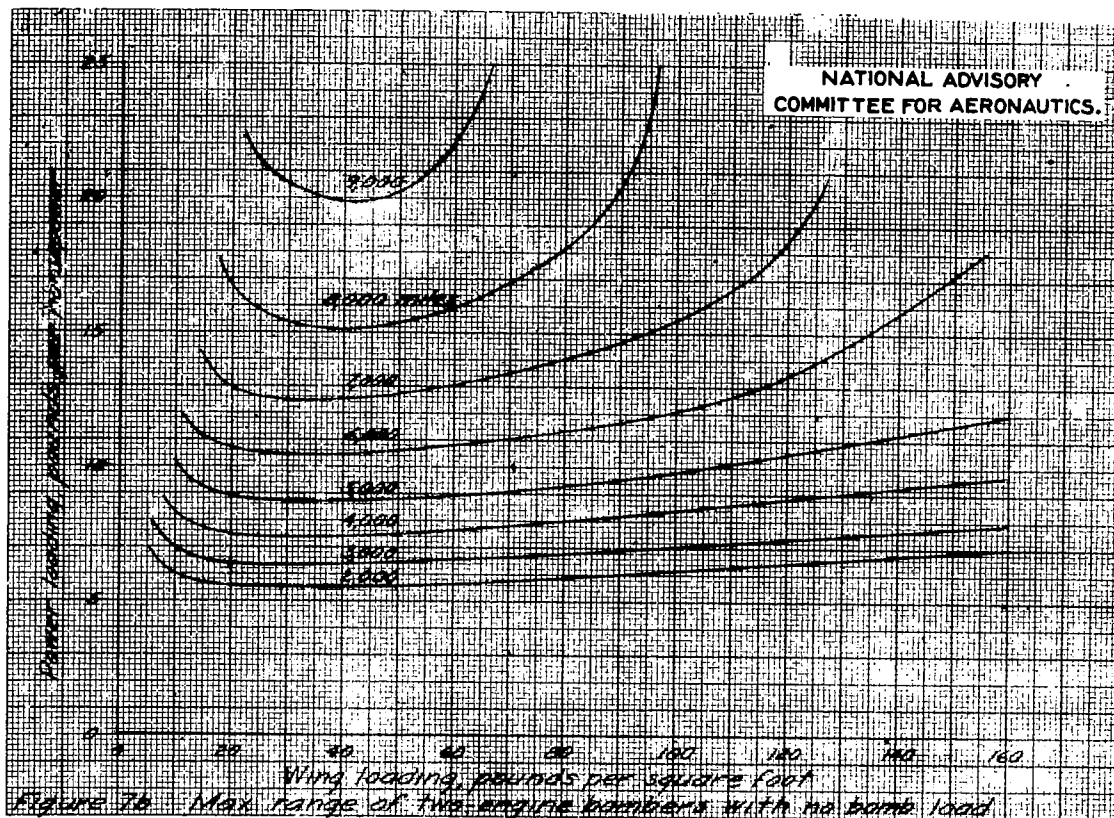
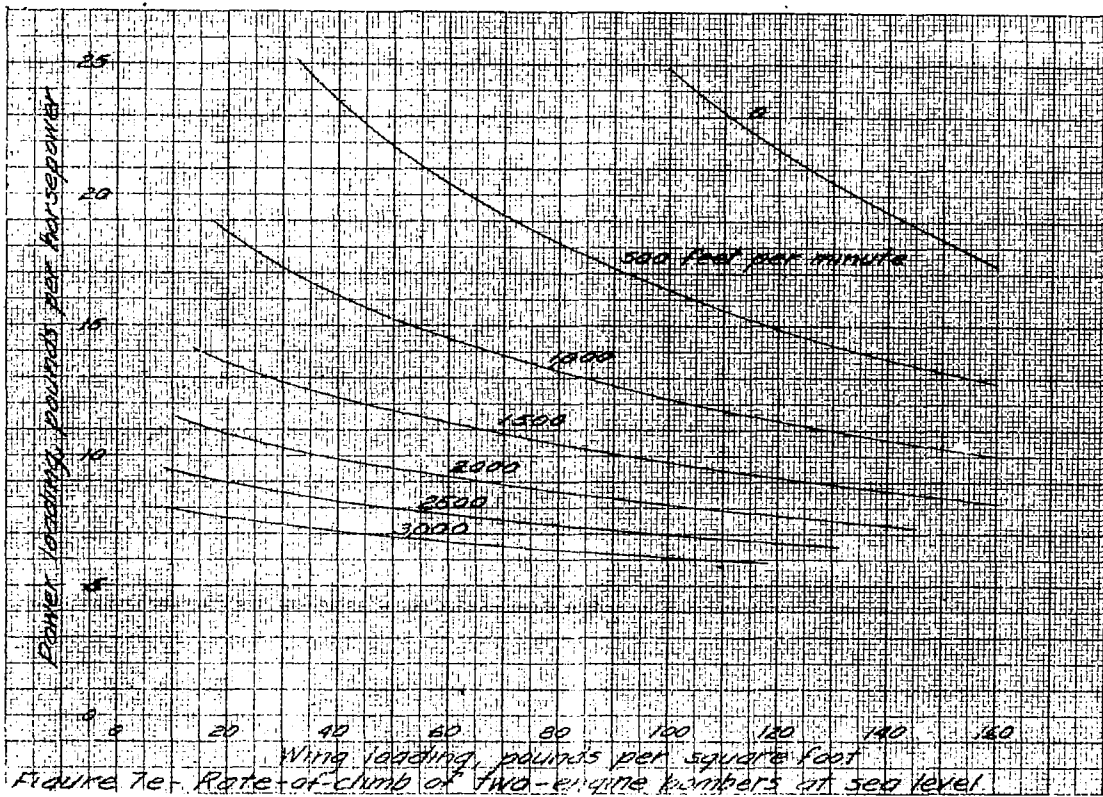
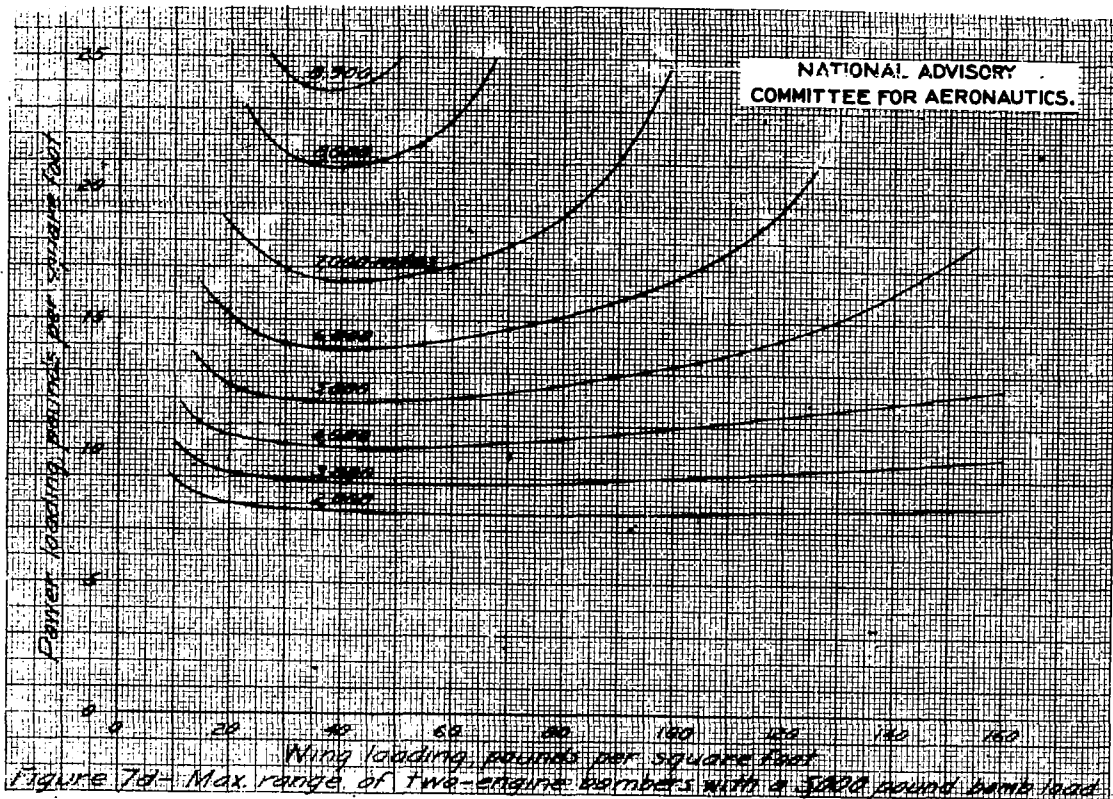


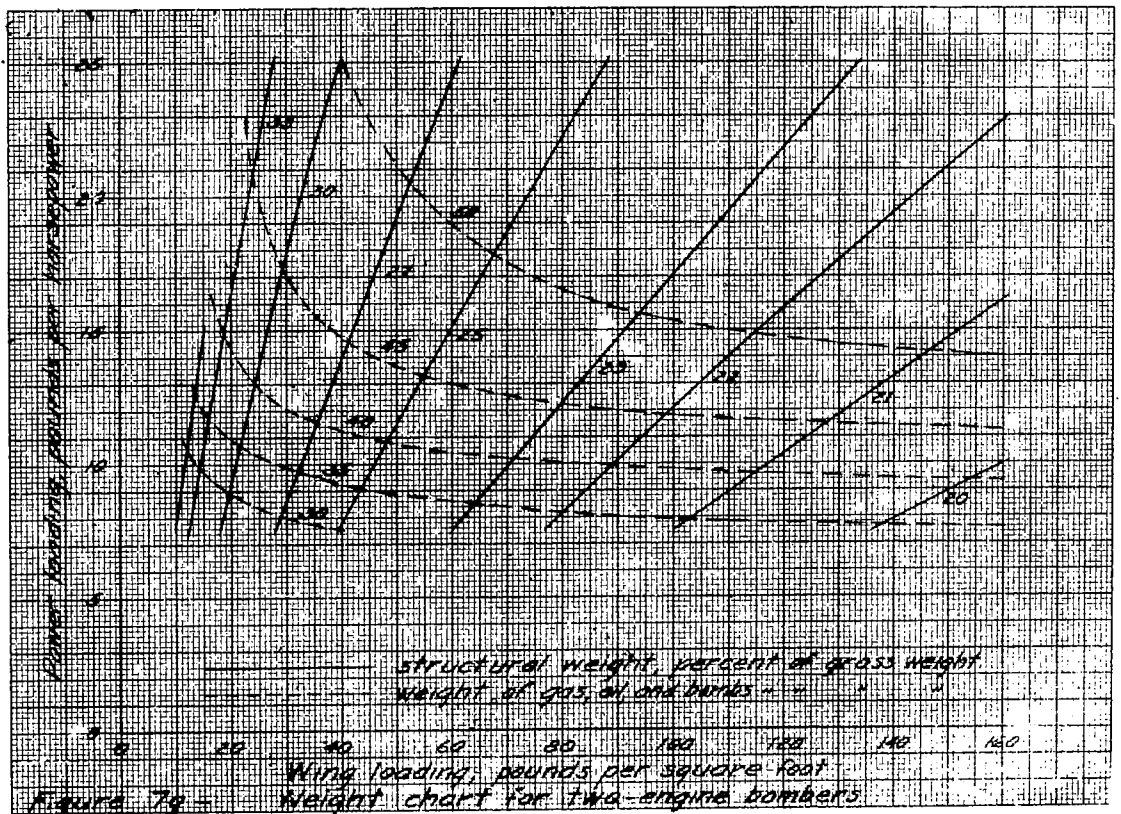
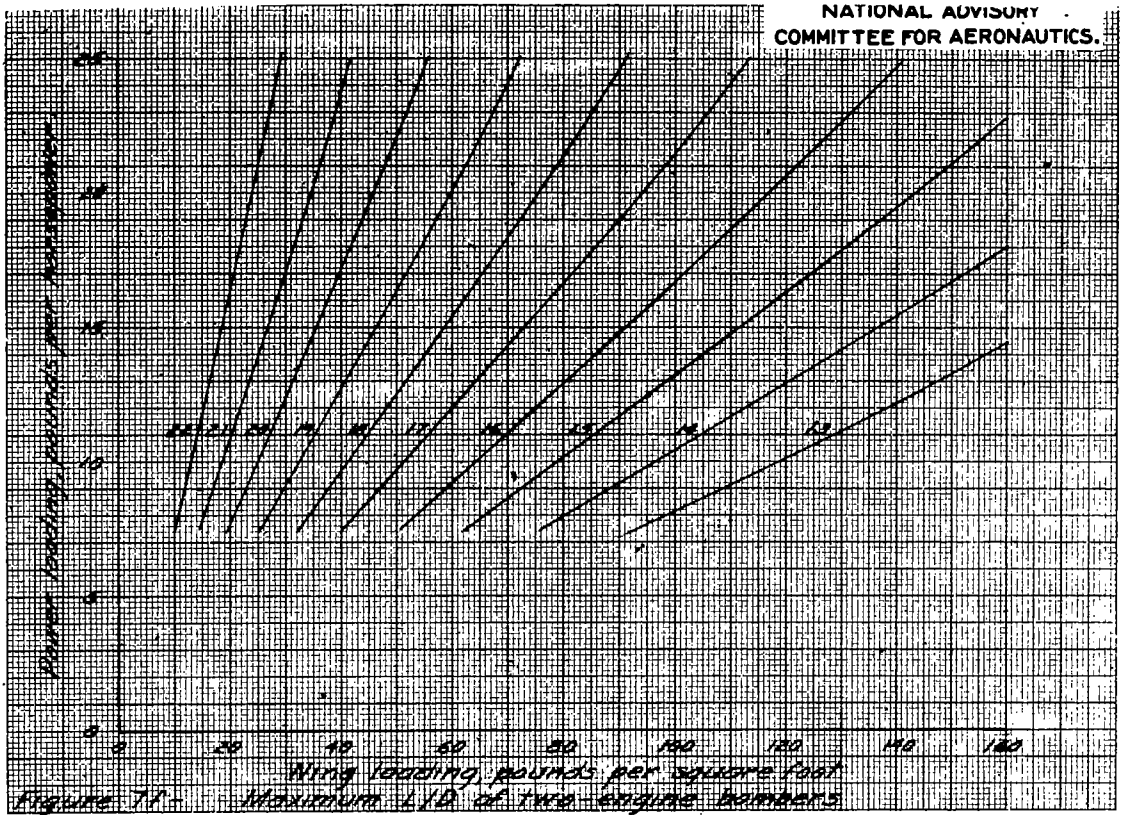
Figure 7a-

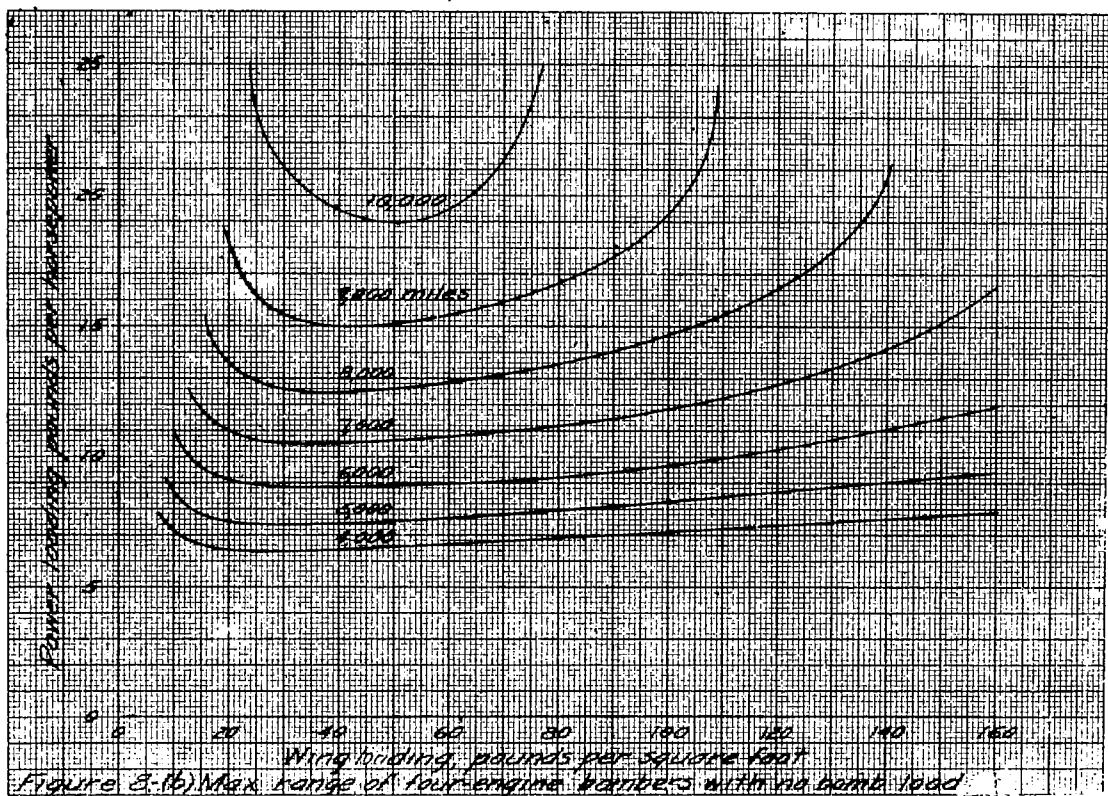
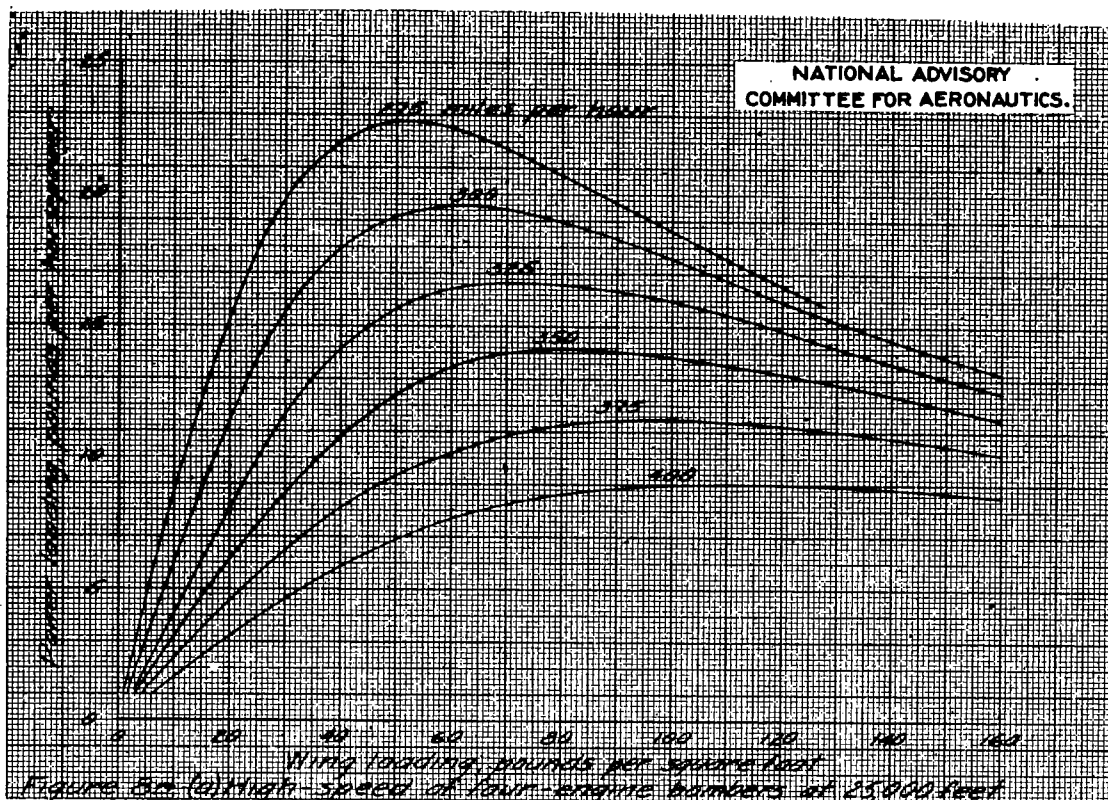
High-speed of two-engine bombers at 25,000 feet

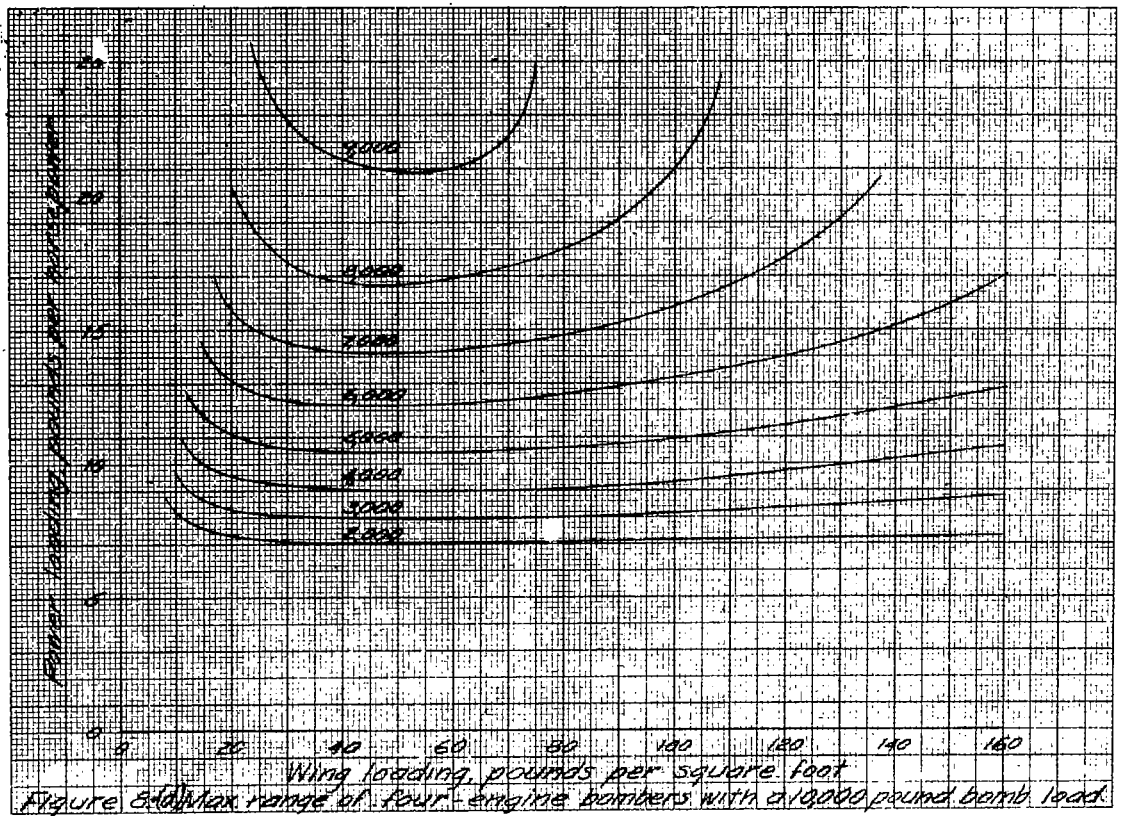
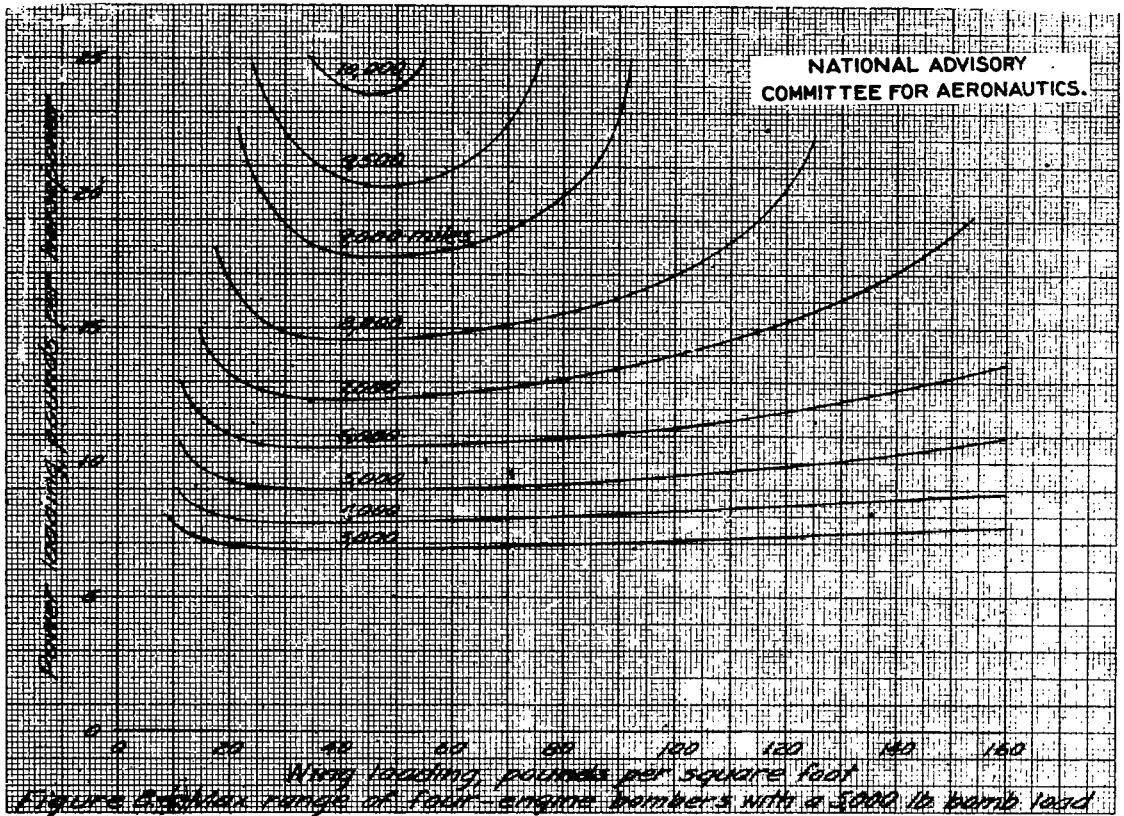




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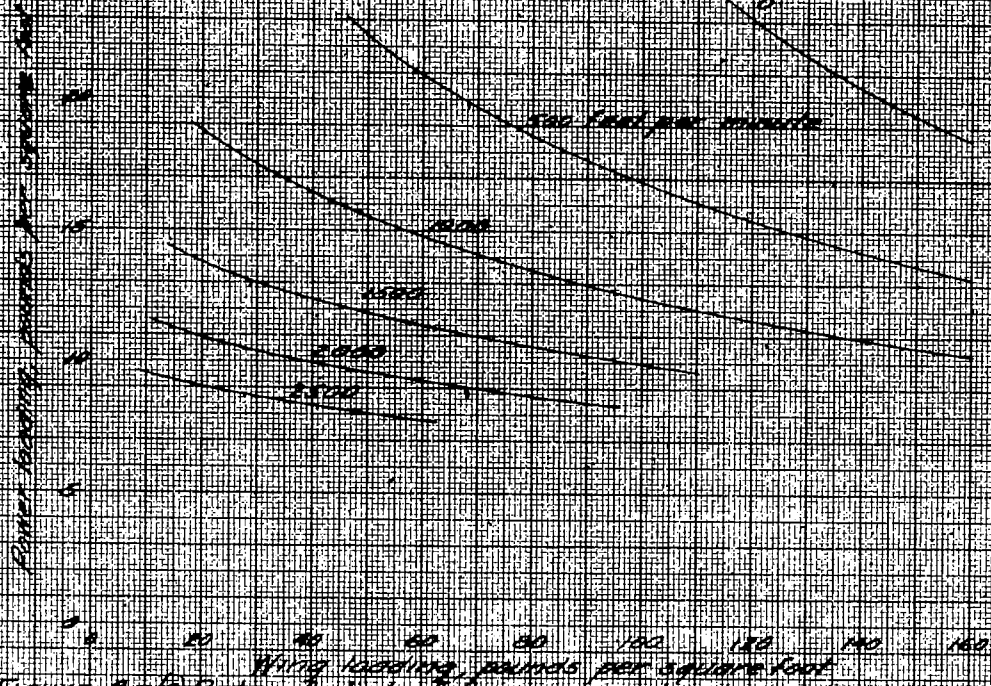


Figure 8. Rate of climb of four-engine bombers at sea level

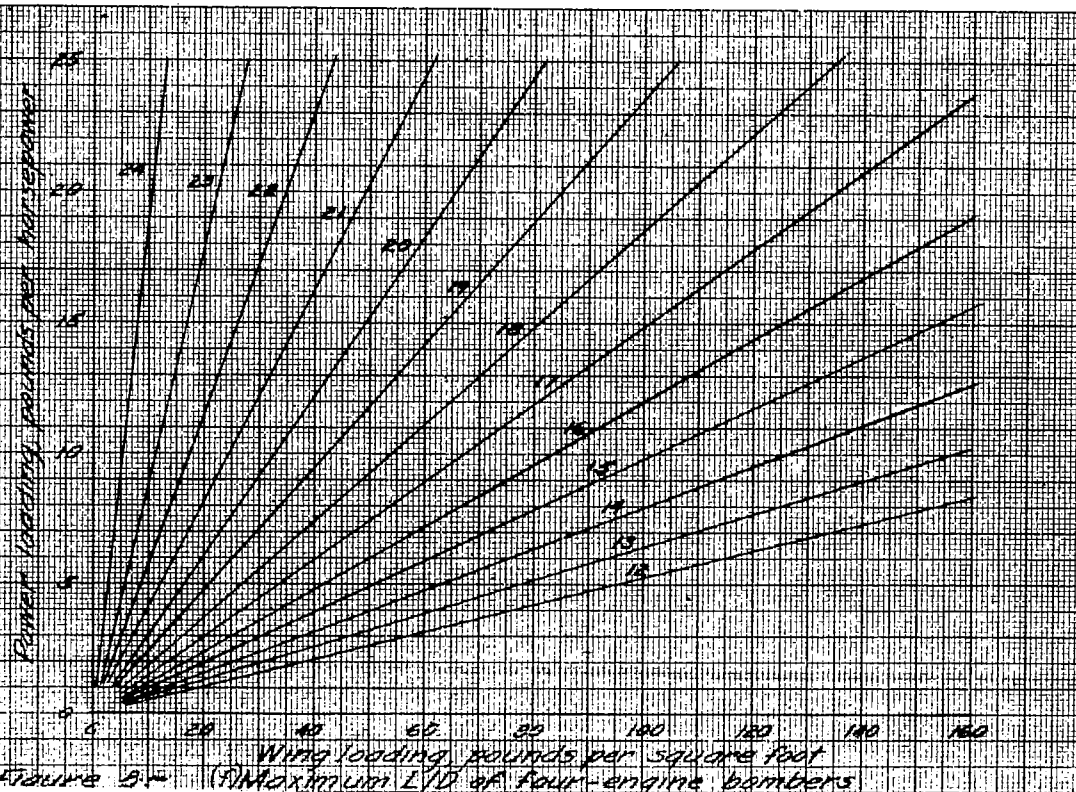


Figure 9. Maximum L/D of four-engine bombers

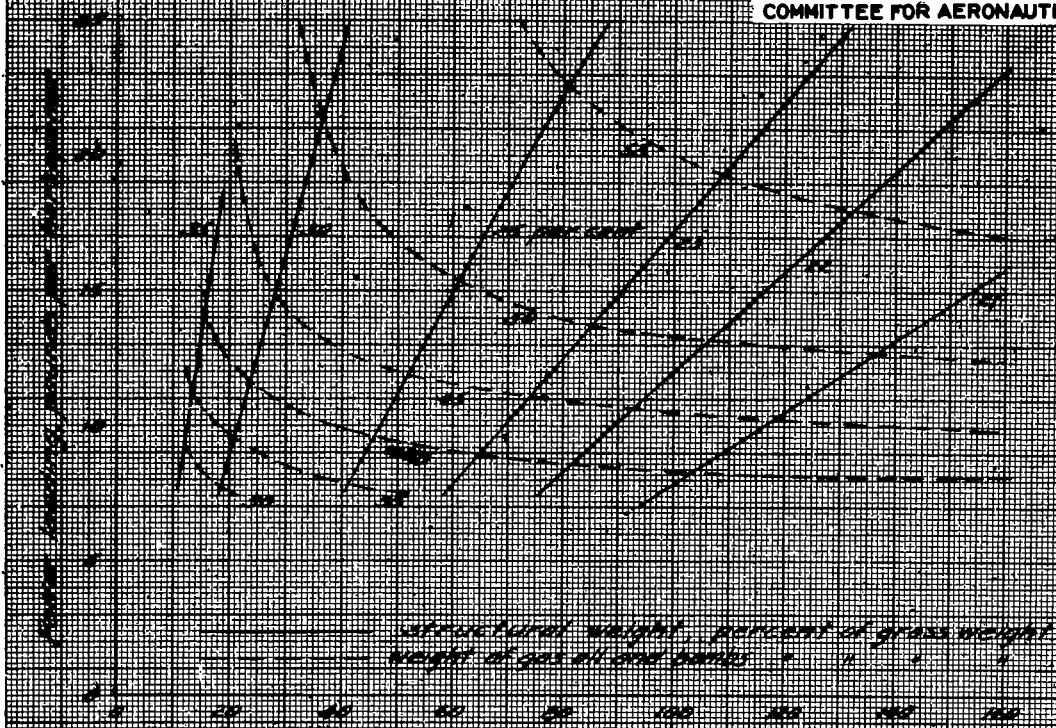


Figure 24. (a) Weight chart for twin-engine bombers.

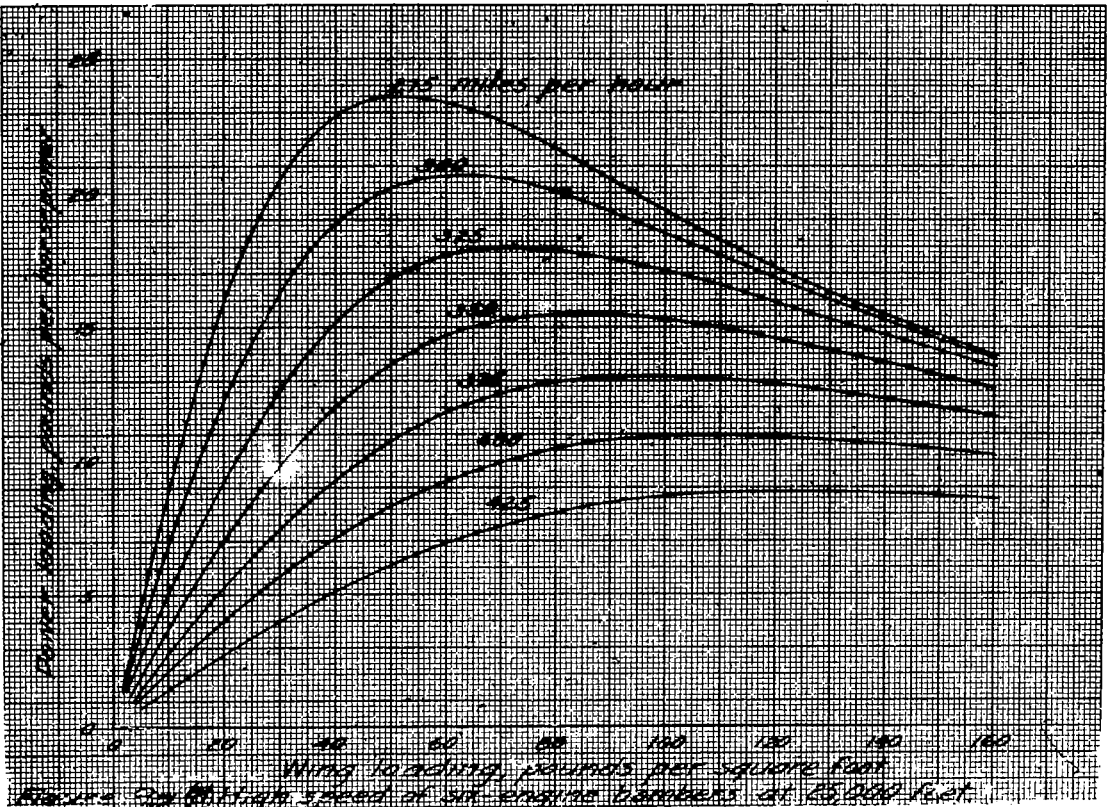


Figure 25. (b) Graph showing speed of six-engine bombers at 25,000 feet.

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Power loading, pounds per horsepower

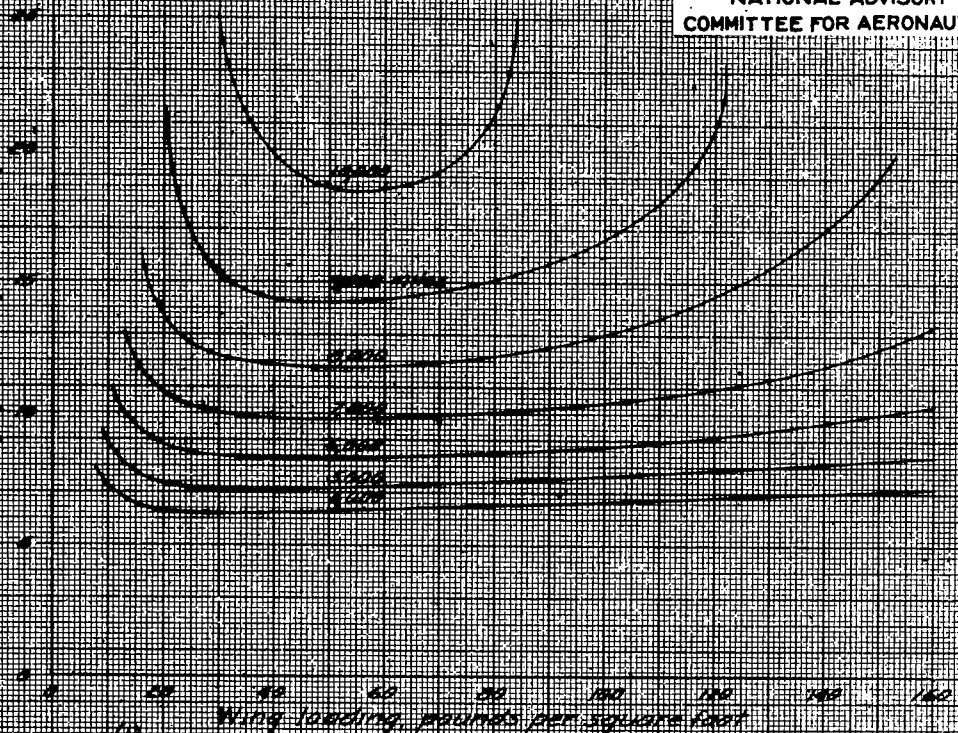


Figure 9-6(a) Max. range of six-engine bombers with no bomb load.

Power loading, pounds per horsepower

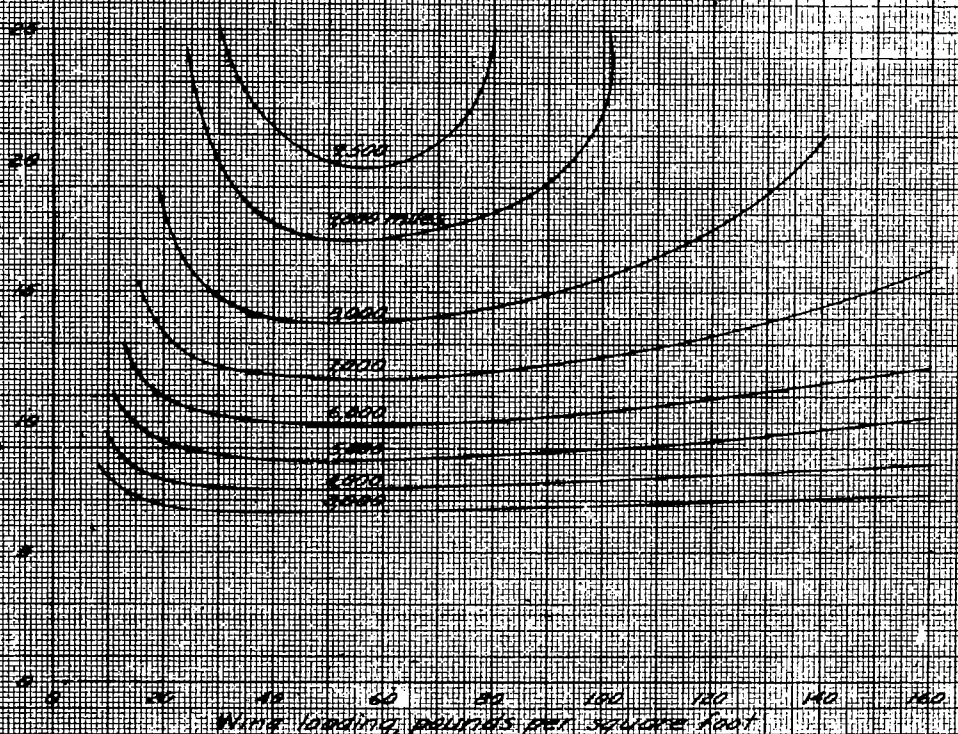
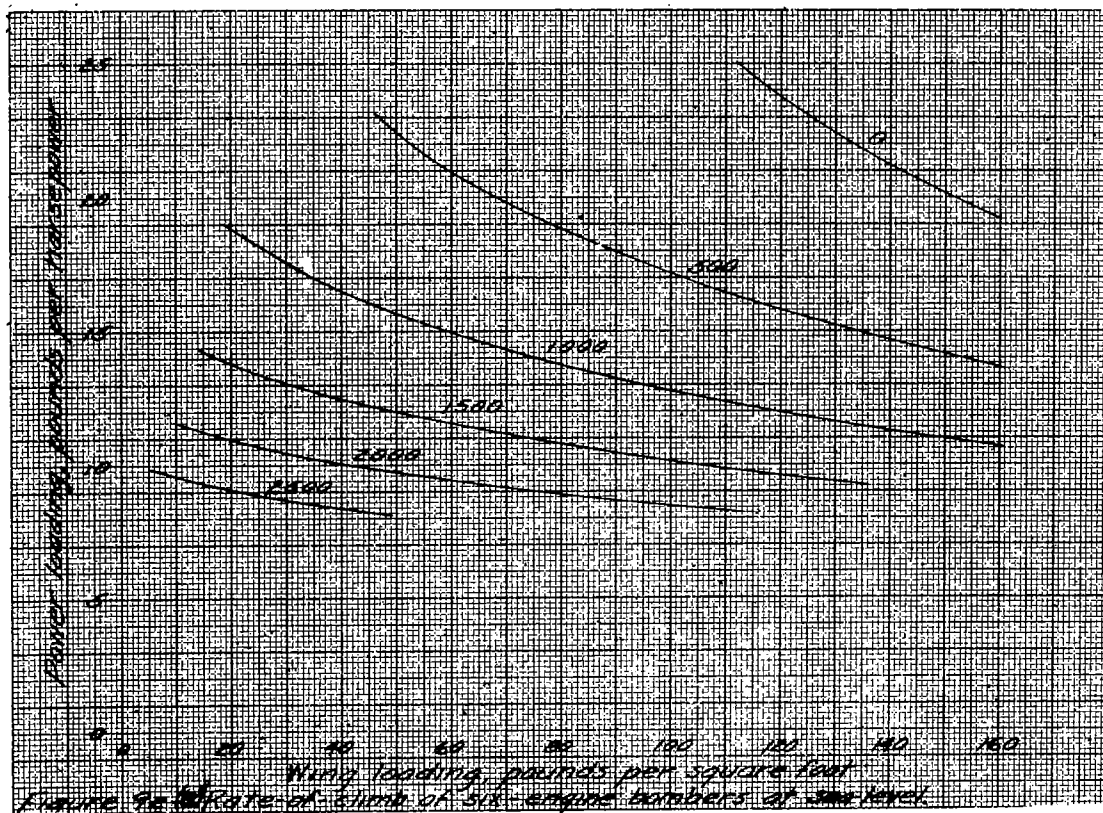
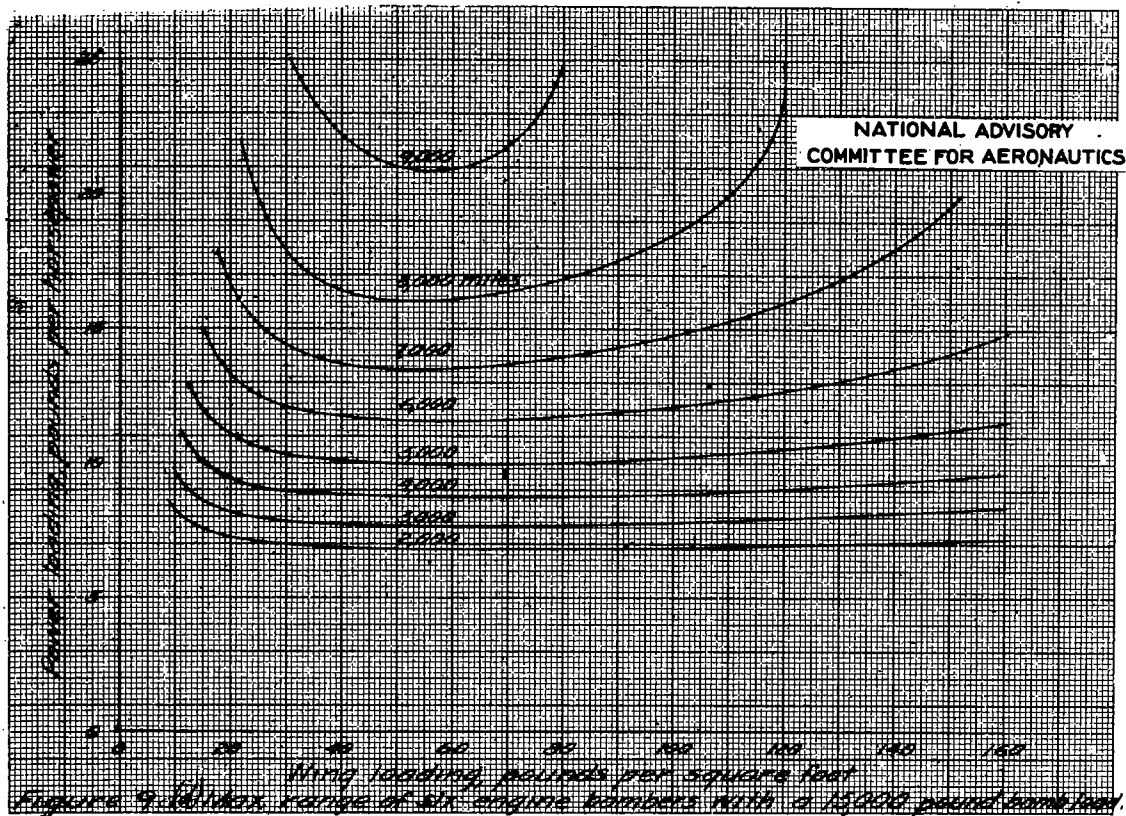


Figure 9-6(b) Max. range of six-engine bombers with a 7,500-pound bomb load.



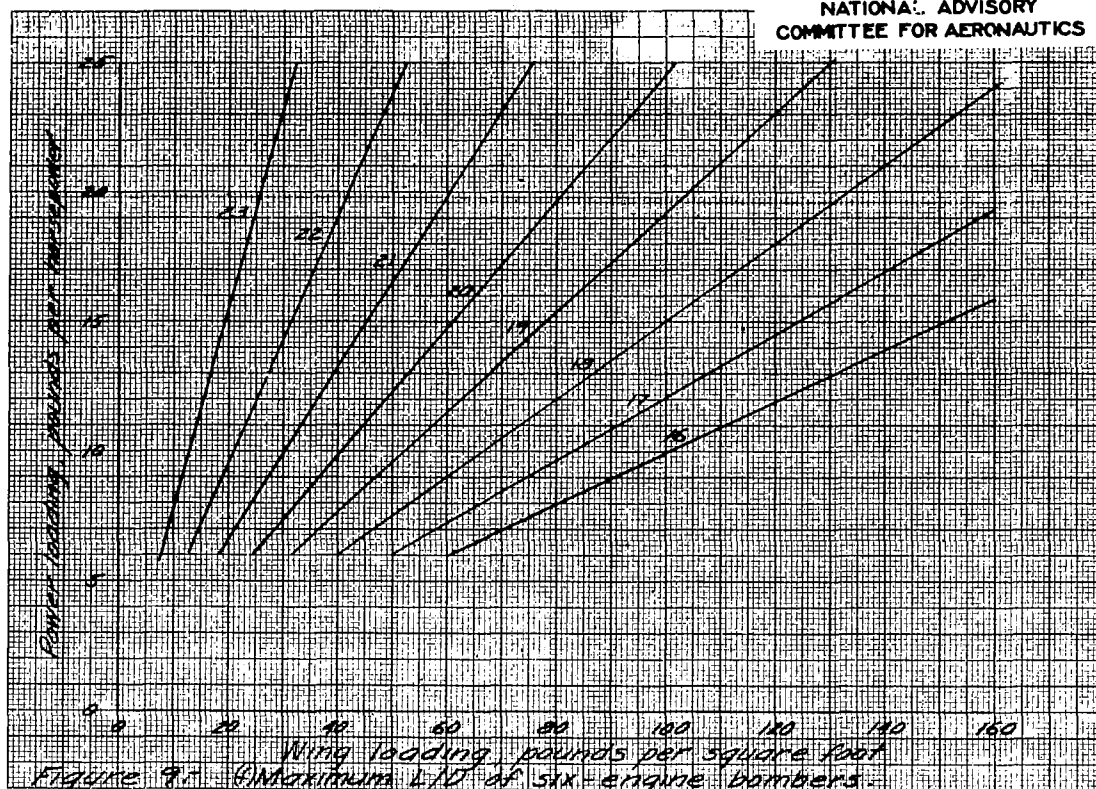


Figure 8: Maximum L/D of six-engine bombers.

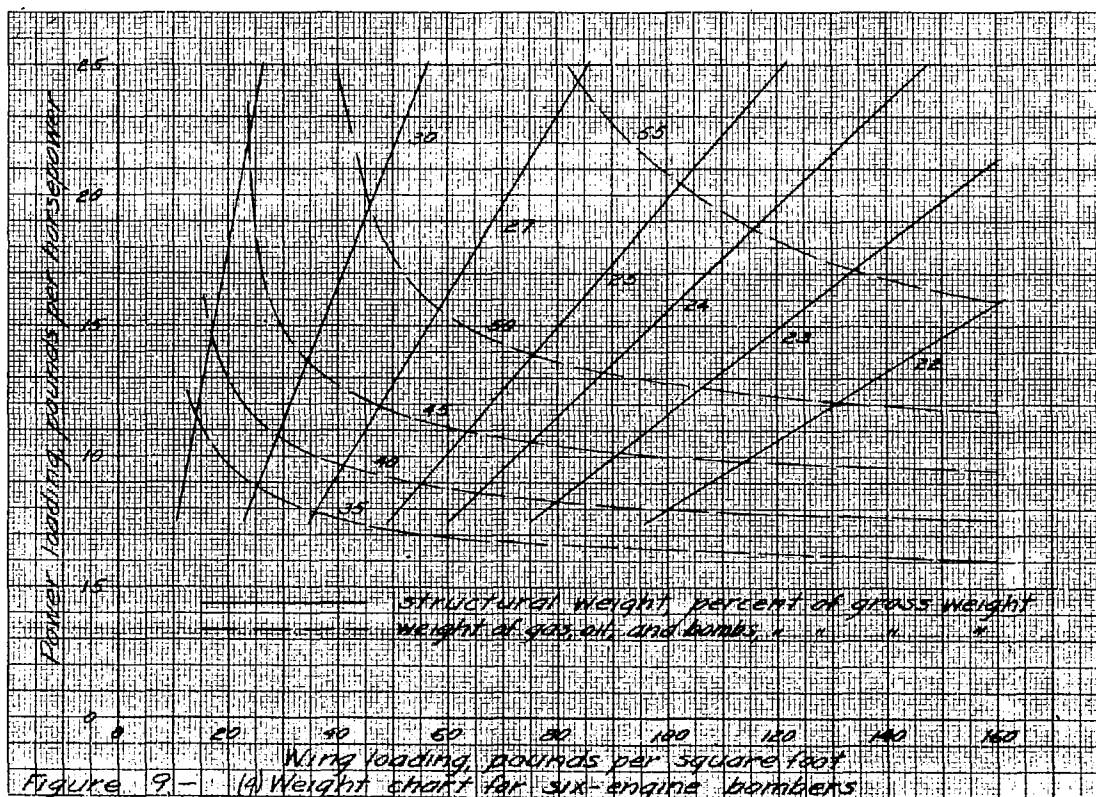


Figure 9 - (A) Weight chart for six-engine bombers

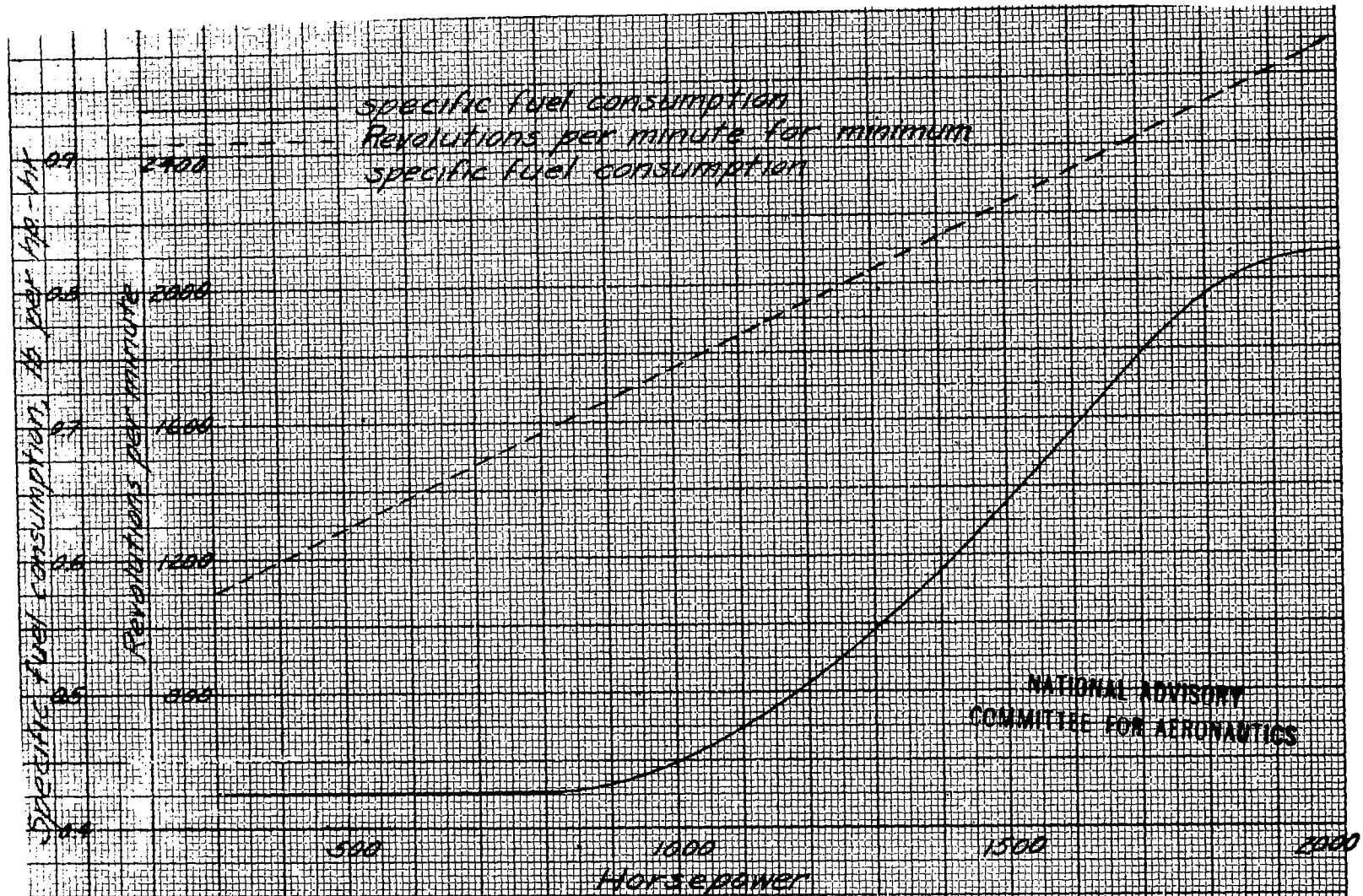


Figure 10. Minimum specific fuel consumption and RPM of 2000-hp engine.

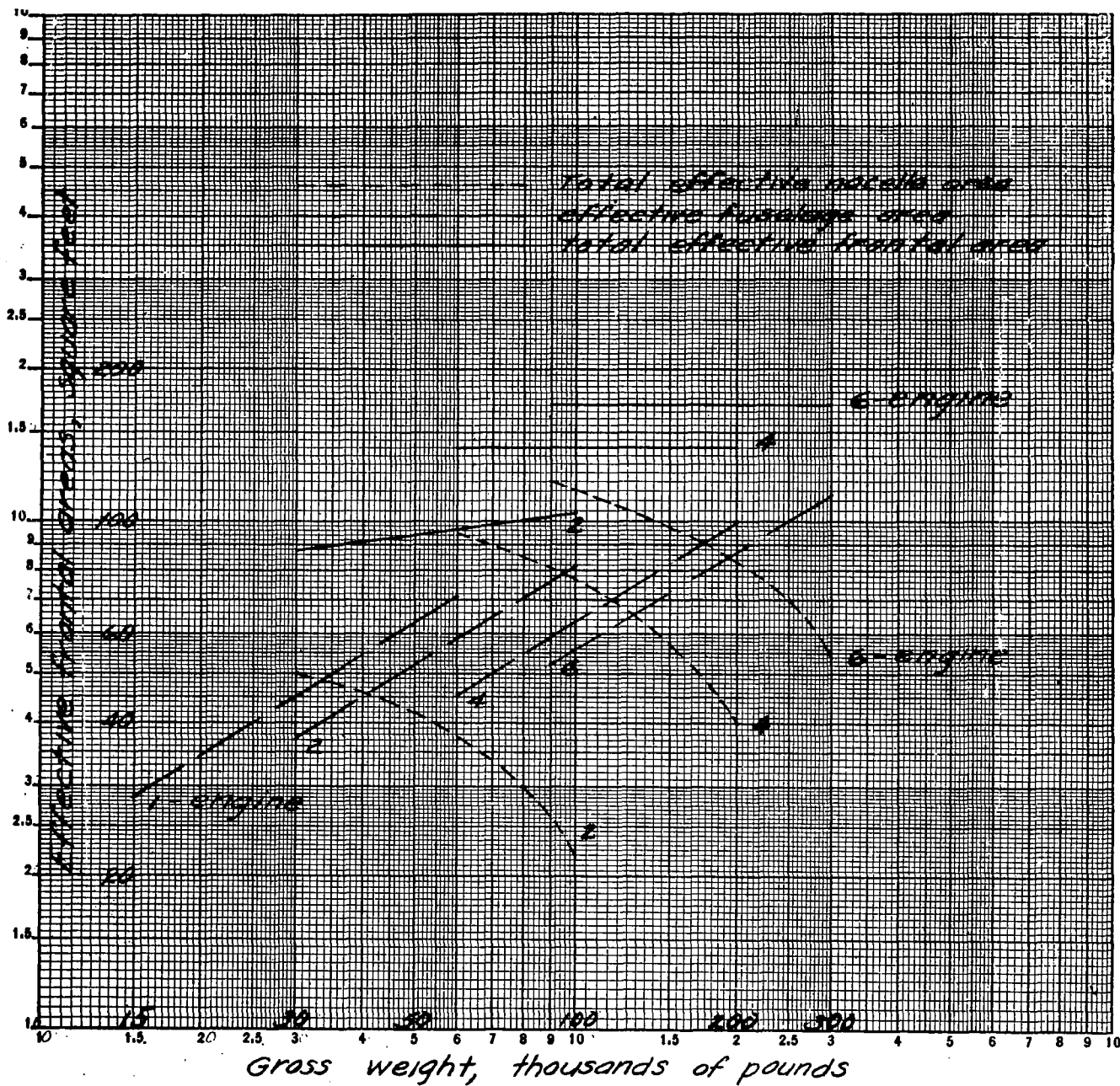


Figure 11:- EFFECTIVE FUSELAGE AND NACELLE FRONTAL AREAS.

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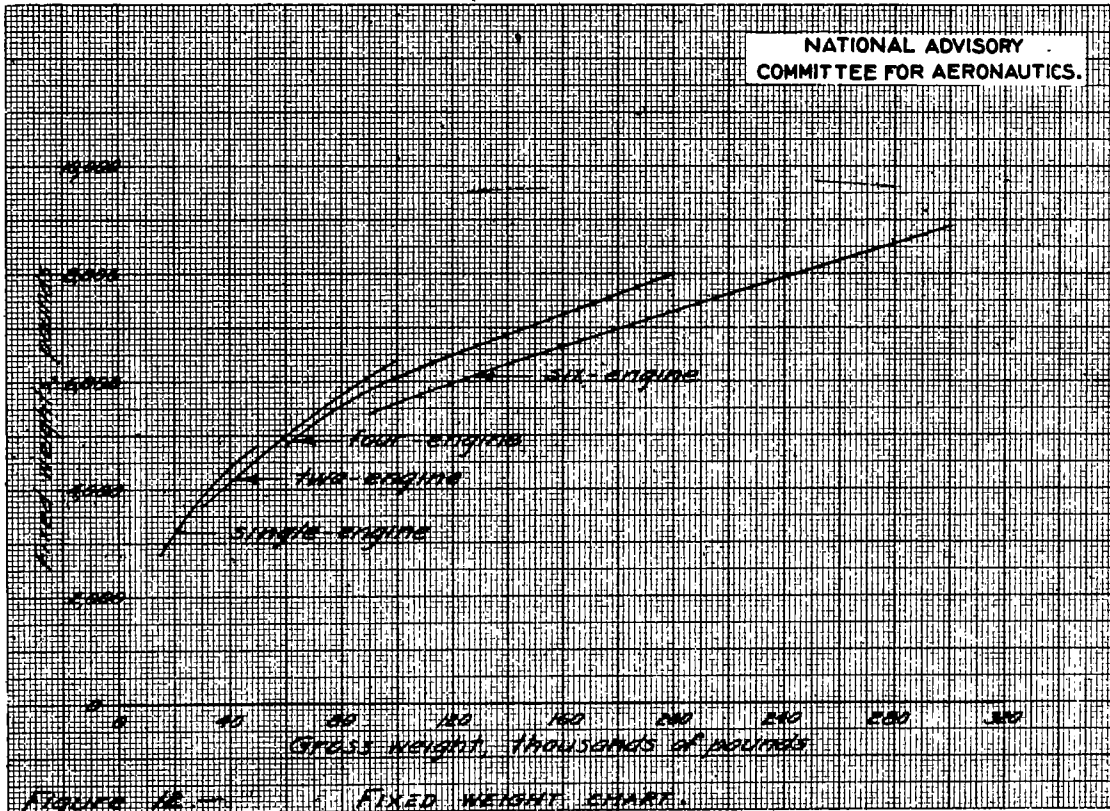


Figure 16. — FIXED WEIGHT CHART.

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